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Water Sustainability Assessments for Four Net Zero Water Installations

Elisabeth M. Jenicek, Laura Curvey, Yuki Cruz, and Rachel Phillips

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Water Sustainability Assessments for Four Net Zero Water Installations

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Abstract

The Army's Net Zero Water (NZW) program for Army installations addresses installation vulnerability to issues of water supply and demand that could jeopardize water security, i.e., the ability of sustainable supply to meet projected demand. Providing the required amount of clean fresh water where needed is becoming increasingly difficult. Understanding regional supply and demand is integral to develop strategies for achieving installation water sustainability. This work evaluated NZW Army installations for vulnerability to water and supply issues to develop strategies to cope with water scarcity and to ultimately support attainment of mission sustainability. This includes the need to understand regional hydrologic systems, to project future water demand, and to identify and document strategies (new sources, conservation, and reuse) to reduce installation demand for fresh water. This project completed installation water sustainability assessments for the last four of eight NZW installations: Aberdeen Proving Ground, MD; Fort Buchanan, PR; Camp Rilea, OR; and Tobyhanna Army Depot, PA (the first four were completed in 2011). This project also examined candidate metrics for evaluating water use efficiency from the Army Campaign Plan. This evaluation explored available data sources and existing centralized data management systems that could be used to facilitate reporting and evaluation.

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Preface

This study was conducted for the Office of the Assistant Secretary of the Army (Installations, Energy and Environment) under Project, “Regional Water Assessment for Four Net Zero Water Installations,” Military Interdepartmental Purchase Request (MIPR) 10201209. The technical monitor was Dr. Marc Kodack, Army Net Zero Water Program Lead.

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), US Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL). The CERL principal investigator was Elisabeth M. Jenicek. Special appreciation is owed to the following installation personnel and other points of contact for providing information and coordination that was invaluable to this demonstration and for reviewing this report: Devon Rust and John Wrobel of Aberdeen Proving Ground, MD; Anabel Negron of Fort Buchanan, PR; Joel Haag, Dan Callahan, and Bob Schilke of Camp Rilea, OR and Jim Arnold of the Oregon National Guard; Tom Wildoner of Tobyhanna Army Depot, PA; Jennifer Morgan of Headquarters, Army Material Command; Oly Thorson of the Army Installation Management Command (IMCOM). At the time of publication, Frank H. Holcomb was Chief, CEERD-CF-E and L. Michael Golish was Chief, CEERD-CF. The Technical Director for Installations was Martin J. Savoie. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director of ERDC-CERL was Dr. Ilker R. Adiguzel.

COL Kevin J. Wilson was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

1 Introduction

1.1 Background

Changing precipitation patterns, coupled with population growth, aging infrastructure, and unsustainable water extraction rates make many US regions vulnerable to water scarcity. In fact, such regional water scarcity is already occurring, even in areas of the United States that were long assumed to be water rich. This growth in regional water demand is worsened by transformation-driven increases in water requirements. As demand for water threatens to outstrip supply, water costs rise. Nevertheless, price is a lagging indicator; the cost of water may not rise precipitously (and thereby lower demand) until emergency conservation measures are needed. This regional and seasonal variance in the availability of water resources places some Army installations in positions of water scarcity. An Army study found that nearly 100 of 411 US installations (23%) are located in watersheds that are highly vulnerable to water crisis situations (Jenicek et al. 2009).

Army installations must meet mandatory water reduction requirements, such as those specified in Executive Order (EO) 13514, the Energy Policy Act of 2005 (EPAct 2005), and the Army's Net Zero Installations initiative. The Army Campaign Plan captures these legislated mandates and includes additional draft metrics intended to evaluate installations' achievements towards greater water efficiency.

1.2 Objectives

The goal of this water sustainability study is to apply the methods developed in *The Army Installation Water Sustainability Assessment* to four additional Net Zero Water Installations: (1) Aberdeen Proving Ground, MD, (2) Fort Buchanan, PR, (3) Camp Rilea, OR, and (4) Tobyhanna Army Depot, PA. The study will project and evaluate the sustainability of water supply and demand over a 30-year time period. This study has the following objectives:

1. To evaluate the pattern of water supply and demand in four Continental United States (CONUS) regions containing NZW Army installations
2. To develop draft metrics associated with water consumption on Army installations

3. To project installation and regional water demand for a period of 30 years
4. To make recommendations on installation strategies for achieving the water reduction goals of the Army Campaign Plan and EO 13514.

1.3 Approach

The objectives of this work were completed through the following steps:

1. Recommendations were developed for proposed water metrics to the Army Campaign Plan MO 8-3.
1. Data were collected for installations and study regions to enable development of regional water sustainability assessment.
2. Regional water supply and demand were evaluated.
3. Region and installation water supply and demand were projected under a number of alternate future scenarios, including, as a minimum, climate change and conservation.
4. Strategies to achieve water sustainability were recommended.
5. Preliminary results were presented to installation staff.
6. Feedback was incorporated into final analyses and documentation.

Research was conducted primarily through available written and on-line resources and by communicating with installation and regional contacts. Site visits also included photographing facilities to aid in drafting the report and for future reference. Draft results were presented on site in all cases to staff deemed appropriate by installation water managers. Water managers routed the draft study results for review at the installation; this included review by security staff.

1.4 Scope

Each installation/region is unique from a water perspective, depending on both the natural features of the region (hydrology, topography, soils, etc.) and the socioeconomic features (level of development, infrastructure, growth potential, etc). These are drivers that will affect water intensity of future demands on the region's resources. However, the process used to assess water sustainability for these four NZW installations is one that could be repeated for any installation-region.

1.5 Mode of technology transfer

It is anticipated that the results of this work will inform decisions about policy and technology related to water conservation and efficiency at the four study installations and across Army installations. The findings from the evaluation of new Army Campaign Plan water metrics are expected to inform decisions about the same issues.

Study results will be made available to the general user community via the US Army Corps of Engineers (USACE) Environmental Community of Practice, the Sustainable Design and Development Water Conservation website, and the Water Management Toolbox publications such as the *Public Works Digest* and *Corps Environment*; and at workshops and symposia. This report will be made available through the World Wide Web (WWW) at URL: <http://libweb.erdcl.usace.army.mil>

2 Overview of Water Policy

Over the past decade, Federal legislation and EOs that stipulate increasingly rigorous water conservation requirements have emerged. The Army has adopted these requirements through policy and regulation, and has advanced the concept even further by establishing challenging targets for installations to achieve “Net Zero Water.” NZW is an emerging sustainable buildings concept analogous to “Net Zero Energy” (NZE). The Army’s Net Zero Water Installation Vision states that:

A Net Zero Water installation limits the consumption of freshwater resources and returns water back to the same watershed so not to deplete the groundwater and surface water resources of that region in quantity or quality (ASA[IE&E] 2011).

Policy areas that impact water include conservation targets for both potable and industrial, landscape and agriculture; new construction and major renovation performance standards; technology standards; and metering and monitoring requirements (often tied to measurement and verification).

2.1 Federal policy

Two main pieces of Federal policy currently govern water efficiency and conservation: EO 13514, *Federal Leadership in Environmental, Energy, and Economic Performance* and the *Energy Independence and Security Act of 2007* (EISA 2007). EO 13514 superseded the earlier 13423, *Strengthening Federal Environmental, Energy and Transportation Management* (2007), although some of the provisions of 13423 remain in effect. The *Energy Policy Act of 2005* (EPAct 2005) required building level metering in all covered facilities by 2016. (Covered facilities are defined based on size and/or amount of water used.) This requirement also remains in effect even though other provisions of EPAct 2005 have been strengthened by newer requirements. (Table 1 lists legislative and regulatory water mandate requirements as of May 2013.)

Table 1. Water mandates, legislative and regulatory requirements as of September 2013.

Federal Mandate	Water Topic	Water Performance Target
EO 13123, June 1999	Reduce water through cost-effective efficiency	FEMP BMPs
EO 13423, January 2007	Water Consumption	Reduce consumption by 2% annually for 16% total by FY15 (FY07 baseline)
	Water Audits	At least 10% per year every 10 years
	Products and Services	Procurement of water efficiency products and services, WaterSense®
Energy Independence and Security Act of 2007	Covered Facilities (75%)	Comprehensive evaluations, project implementation, and follow-up
	Post-Construction Stormwater	Restore to predevelopment hydrology
EO 13514, October 2009	Water Consumption	Reduce consumption by 2% annually for 26% total by FY20 (FY07 baseline)
	Industrial, Landscape, Agricultural	Reduce consumption by 2% annually for 20% total by FY20 (FY10 baseline)
	Water Reuse	Identify, promote, and implement water reuse strategies
	Stormwater Management	Implement and achieve objectives from USEPA
Army Sustainable Design and Development Policy, October 2010	New Construction and Renovation	Achieve 30% reduction compared to baseline IAW American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 189.1-2009 Outdoor use achieve a 50% reduction
Army Campaign Plan	Major Objective 8-3	8 candidate water metrics

EO 13514 superseded the requirements of EO 13423 in the development of water management plans and implementation of Best Management Practices (BMPs) for water efficiency as identified by the Department of Energy's Federal Energy Management Program (FEMP). EO 13423 required a 2% annual reduction in water consumption intensity (gal/sq ft) from a 2007 baseline through the end of FY15, or 16% by the end of FY15. It further required water audits at Federal facilities of at least 10% of facility square footage at least once every 10 years. Finally, it encouraged the procurement and use of water efficient products and services, specifically identifying the US Environmental Protection Agency's (USEPA's) WaterSense® program as a source of guidance.

Additionally, BMPs were originally developed by FEMP in response to the requirements set forth in *EO 13123, Greening the Government through Efficient Energy Management*, which required Federal agencies to reduce water use through cost-effective water efficiency improvements. In response to *EO 13423* and to account for recent changes in technology in water use patterns, the USEPA's Water Sense Office updated the original BMPs. The updated BMPs, which were developed to help agency personnel

achieve water conservation goals of *EO 13423*, are available at the FEMP web site: http://www1.eere.energy.gov/femp/program/waterefficiency_bmp.html

The *Energy Independence and Security Act of 2007* (EISA 2007) amends Section 543 of the *National Energy Conservation Policy Act*, the foundation of most current energy requirements. It adds further water conservation requirements and provides guidance for benchmarking. Under EISA 2007, agencies are required to categorize groups of facilities that are managed as an integrated operation and to identify “covered facilities” that constitute at least 75% of the agency’s facility energy and water use. Each of these covered facilities will be assigned an energy manager responsible for completing comprehensive energy and water evaluations, implementing efficiency measures, and following up on implementation.

EISA 2007 also addresses post-construction stormwater management for Federal projects, requiring that:

The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5000 sq ft (465 m²) shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

EO 13514 expands the water efficiency and conservation requirements of *EO 13423* and *EISA 2007*. This mandate extends *EO 13423*’s 2% annual water consumption intensity reduction requirement into FY20, resulting in a total water reduction requirement of 26% from the baseline year of 2007. Additionally, the new rules require a 2% annual reduction for agency industrial, landscaping, and agricultural water consumption through 2020, for a total of 20% water consumption reduction relative to the 2010 base year. *EO 13514* also encourages agencies to identify, promote, and implement water reuse strategies that reduce potable water consumption and support objectives identified in the stormwater management guidance issued by the USEPA.

2.2 Army policy

Army water policy interprets both US Department of Defense (DOD) and Federal policy. Documents include Army Regulations (ARs), technical standards, policy memos, and general guidance documents. In addition,

the Army provides guidance on a range of specific water topics such as metering and setting rates for reimbursable customers.

AR 420-1, *Army Facilities Management* (HQDA 2008), covers energy and water management in Chapter 22-11. This guidance covers conservation guidelines, funding programs, metering and audits, reporting, awareness, and award programs. AR 420-41, *Acquisition and Sale of Utilities Services* (HQDA 1990), calls for water supply and wastewater services to be provided at the lowest Life Cycle Cost (LCC) consistent with installation and mission requirements, efficiency of operation, reliability of service, and environmental considerations. The costs for these services are to be held to a minimum through comprehensive water resource planning, management, and an effective water conservation program — all of which rely heavily on the adoption of sustainable water technologies. Furthermore, AR 420-41 also requires compliance with the Safe Drinking Water Act (SDWA).

Technical guidance can be found on the Whole Building Design Guide website, at URL: http://www.wbdg.org/ccb/browse_cat.php?o=31&c=214. This includes Army and Corps of Engineers Criteria to include Architectural and Engineering Instructions, Design Guides, Engineer Manuals, Technical Bulletins, and Engineering and Construction Bulletins (ECBs), which are used to promulgate changes in requirements or processes related to building design.

2.2.1 Army Campaign Plan

The *Army Campaign Plan* (HQDA 2012) addresses water sustainability under Campaign Objective 8, “Achieve Energy Security and Sustainability Objectives.” Major Objective 8-3, “Improve Water Security and Sustainability across Army Installations and Forward Operations,” has the desired strategic outcome: “Assured access to reliable supplies of water and the ability to protect and deliver sufficient water to meet mission essential requirements” (HQDA 2012). Major subtasks currently relate to reduction of potable water consumption intensity at permanent installations; reduction of industrial, landscaping and agricultural water consumption; and increased use of alternative water sources. Metrics under development include:

- percentage of potable water distribution system assessed for leaks annually
- percent reduction in potable water intensity measured in gallons/capita/day

- percent reduction in irrigation, landscaping and agricultural water consumption
- percent of shower water reuse systems fielded
- percent reduction in potable water consumed by the supply chain (water footprint).

2.2.2 Army Energy Security Implementation Strategy

The *Army Energy Security Implementation Strategy* (AESIS), signed 13 January 2009, addresses both energy and water security. This policy stresses the enhanced operational capability that is supported through achievement of the Army's energy and water goals. Progress towards meeting AESIS metrics is being tracked using the Army Strategic Management System.

2.2.3 Army water portfolio

The Army's Water Portfolio includes details about the Army Water Vision 2017, DOD and Army water guidance, moving to water security, BMPs and projects, major water programs, and the way ahead. The portfolio is available on the Office of the Assistant Chief of Staff, Installation Management (OACSIM) web site, at URL:

http://army-energy.hqda.pentagon.mil/programs/water_portfolio.asp

2.2.4 Sustainable Design and Development Policy

The Army's *Sustainable Design and Development Policy Update (Environmental and Energy Performance)* (DA 2010) updates and supersedes the policy of 8 July 2010. The revision includes incorporation of sustainable development and design principles, following guidance as detailed in ASHRAE Standard 189.1-2009. All facility construction projects shall achieve a 30% reduction in indoor potable water use as compared to a baseline using guidance from ASHRAE. In addition, outdoor potable water consumption shall achieve a reduction of 50% from the baseline (DA 2010). This policy is currently under revision (September 2013).

2.2.5 Standards and codes

Plumbing and building codes influence the adoption of water efficient products and processes. DOD adopts the International Code Council (ICC) International Plumbing Code (IPC) as the primary standard for DOD facil-

ity plumbing systems. The code has a 3-year development cycle for updates. The process of amending codes is long and labor-intensive and requires the support of water stakeholders. Any additions, deletions, and revisions to the IPC are listed in Appendix A of the “Supplemental Technical Criteria” of Unified Facilities Criteria (UFC) 3-420-01 (HQUSACE, NAVFACENCOM, AFCEA 2009).

WaterSense® is a USEPA partnership program that certifies water fixtures that meet rigorous criteria in both performance and efficiency. Specifications and criteria are available for bathroom sink faucets, shower heads, toilets, urinals, and landscape irrigation controls. The pre-rinse spray valve specification is in the public review stage with release anticipated during Fiscal Year 2013 (FY13).

The US Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED®) Green Building Rating System is a voluntary standard for high performance sustainable buildings. LEED® certification validates that a building is a high performing, sustainable structure. Certification also benchmarks a building’s performance to support ongoing analysis over time to quantify the return on investment of green design, construction, systems, and materials. All Military Construction, Army (MCA) projects meeting the Minimum Program Requirements for LEED® certification are to be planned, designed, and built to be Green Building Certification Institute (GBCI) certified at the Silver level or higher. WE 1, the Water Efficient Landscaping credit and WE 3, the Water Use Reduction (30% reduction) credit are required in all MCA projects.

ASHRAE developed Standard 189.1-2009 in conjunction with the USGBC and the Illuminating Engineering Society (IES). This standard is intended to provide minimum requirements for sustainable or green buildings through the general goals of reducing energy consumption, addressing site sustainability, water efficiency, occupant comfort, environmental impact, materials, and resources. The Army adopted the energy and water standards of *ASHRAE 189.1-2009* for all new construction and major renovations through the *Sustainable Design and Development Policy*.

2.2.6 Army Net Zero installations program

The Army Net Zero program was established in October 2010 by the Honorable Katherine Hammack, Assistant Secretary of the Army, Installations, Energy and Environment. Net Zero was conceived as a force multiplier, that is, a means to steward available resources and to manage costs to better support soldiers, families and civilians. Net Zero also supports resource security and sustainability.

The Army's Net Zero Water Installation Vision states that:

A Net Zero Water installation limits the consumption of freshwater resources and returns water back to the same watershed so not to deplete the groundwater and surface water resources of that region in quantity or quality over the course of a year.

Definitions and guidance for installations to achieve NZW is provided on the Army Energy Program web site and contained in the Net Zero Water Guidelines:

The Net Zero Water strategy balances water availability and use to ensure sustainable water supply for years to come. This concept is of increasing importance since scarcity of clean potable water is quickly becoming a serious issue in many countries around the world. The continued drawdown of major aquifers results in significant problems for our future. Strategies such as harvesting rain water and recycling discharge water for reuse can reduce the need for municipal water, exported sewage or stormwater. Desalination can be utilized to convert briny, brackish or salt water to fresh water so it is suitable for human consumption or irrigation.

To achieve a Net Zero Water installation, efforts begin with conservation followed by efficiency in use and improved integrity of distribution systems. Water is repurposed by utilizing grey water generated from sources such as showers, sinks, and laundries and by capturing precipitation and stormwater runoff for on-site use. Wastewater can be treated and reclaimed for other uses or recharged into groundwater aquifers. Several Army installations are already well down the path to reaching Net Zero Water goals (OACSIM 2013a).

Net Zero installations were selected from self nominations in April 2011. There are five Net Zero Energy sites, six Net Zero Water sites, and six Net Zero Waste sites. In addition, two installations were designated Net Zero Energy-Water-Waste. Figure 1 shows a map view of the pilot installations.

An initial Net Zero training workshop was held at Fort Detrick, MD in June 2011. A second training workshop was held in Chicago, IL in January 2012. Individual focus area workshops (energy, water and waste) were held separately in late FY2012. The purpose of the workshops was to engage with installation resource managers in an information exchange, both to gauge installation progress towards Net Zero goals and to share lessons learned and technology updates. FY13 Net Zero training is taking place “virtually” due to budget constraints.

Figure 1. National map showing Army Net Zero pilot installations.



3 Water Metrics

The Army Campaign Plan (ACP) is part four of The Army Plan. The ACP operationalizes Army strategy. The 2012 ACP has nine Campaign Objectives, which are sub-divided into multiple Major Objectives with multiple metrics. Each Campaign Objective is the responsibility of an Assistant Secretary of the Army. The Assistant Secretary of the Army (Installations, Energy and Environment) has responsibility for Campaign Objectives 2.0 (Facilities, Programs and Services to Support the Army and Army Families) and 8.0 (Achieve Energy Security and Sustainability Objectives).

Water security falls under Campaign Objective 8, Major Objective 8-3, *Enhance Water Security*. The desired strategic outcome is assured availability of water for all Army missions. Water security is the capacity to ensure that water of suitable quality is provided at a sustained rate sufficient to support all current and future Army missions, as needed. Within 8-3, there are eight metrics, six of which are proposed to address water efficiency and conservation. Chapter 2 of the proposed metrics recommends criteria and data sources, and establishes draft operational definitions (Appendix B).

The first objective of this project was to recommend operational definitions for two proposed water metrics to the ACP, MO 8-3. The operational definition consists of title, weight, strategic outcome, and definition.

3.1 Potable water distribution system linear feet assessed for leaks (candidate metric 8-3.1.1)

Unaccounted-for water, or water loss, is a common concern on Army installations. The lack of metered data combined with the aging water infrastructure and shrinking operations and maintenance budgets highlight the importance of prioritizing leak detection and repair. The Army recognizes the critical nature of infrastructure condition and includes a candidate metric for potable water leak detection in the ACP. Leak detection surveys fall under the US Department of Energy (USDOE) FEMP BMP #3: *Distribution System Audits, Leak Detection, and Repair*.

Metric reporting should be simple and rely on existing methods and data. Several enterprise systems could support centralized reporting of the leak detection metric. Other means of assessing water loss may be possible at some locations. Ideally, the amount of potable water purchased/produced by an installation should be very close to the amount of wastewater exported/processed in the installation wastewater treatment plant. The difference between these values could provide some information on the extent of water loss. This assessment should also take into account any waters not returned to the wastewater system—line flushing, evaporation, unmetered ILA, swimming pools—or gains to system from inflow and infiltration.

3.1.1 Background

A comprehensive assessment of Army installation water distribution systems has not been completed. Recent water sustainability assessments at 14 CONUS and three Outside Continental United States (OCONUS) sites determined that many installations were unaware of the extent of their water loss. The cost of unaccounted-for water includes wasted energy and treatment chemicals, liability from damage, loss of infrastructure capacity, increased flows to sewer collection systems and wastewater treatment, in addition to wasted water (e.g., see Figure 2). While standards for technical performance, increased efficiency, and reduced use have been implemented, no such standards exist for leak detection or repair. Improvements in metering and leak detection are necessary to reduce water loss.

Infrastructure condition is important for several reasons. Many drinking water utilities are not able to meet the demands of their users. Identifying and correcting water loss provides increased supply. Water leaks that are not identified and repaired can cause more costly problems in the future, such as sink holes beneath streets, damaged building foundations, or the dumping of chlorinated water into nearby aquatic ecosystems. The cost of this “collateral damage” is much higher than the revenue cost of the water (Rafter 2013). A critical side effect of degraded water infrastructure is unreliable water delivery coupled with a reversal in environmental and public health gains. Installations are required by code to separate water service pipe and building sewer by at least 5 ft of undisturbed or compacted earth (ICC 2011).

Figure 2. Leaks that are ignored can cause disruptive and costly failures.



Source: AWWA (2012a).

One reason that the condition of municipal distribution systems is important to the Army is that, for installations that purchase water from municipal utilities, high rates of water loss can affect the availability of water to the post. A second reason is that it is likely that the condition of water distribution systems on Army installations is similar to that of comparable age systems outside the fence in terms of material, design and pipe age. This is because adjacent municipalities typically expanded at the same pace as the post. Privatized distribution systems on post offer special challenges. Contractors are bound by the specific language of each contract. The utility privatization (UP) process has evolved over time and contract language varies. ACSIM documents a water reduction of 28% more at 20 privatized installations as compared to Army-owned systems (OACSIM undated).

The reality of water loss through distribution system leakage was addressed by the Army in one form through establishment of the Utilities Privatization Program. UP contracts contain requirements for leak detection and repair along with upgrades and regular maintenance of water distribution systems in accordance with industry and environmental standards (Gray 2013).

3.1.2 Overview of national water infrastructure condition

Water infrastructure is one of the most expensive infrastructure assets. The mains themselves are largely unseen, but comprise over 70% of the value of the system. Much of the nation's water infrastructure was built following a boom in development after passage of the 1972 amendments to the Federal Water Pollution Control Act, now known as the Clean Water Act (33 USC 1251 et seq.).

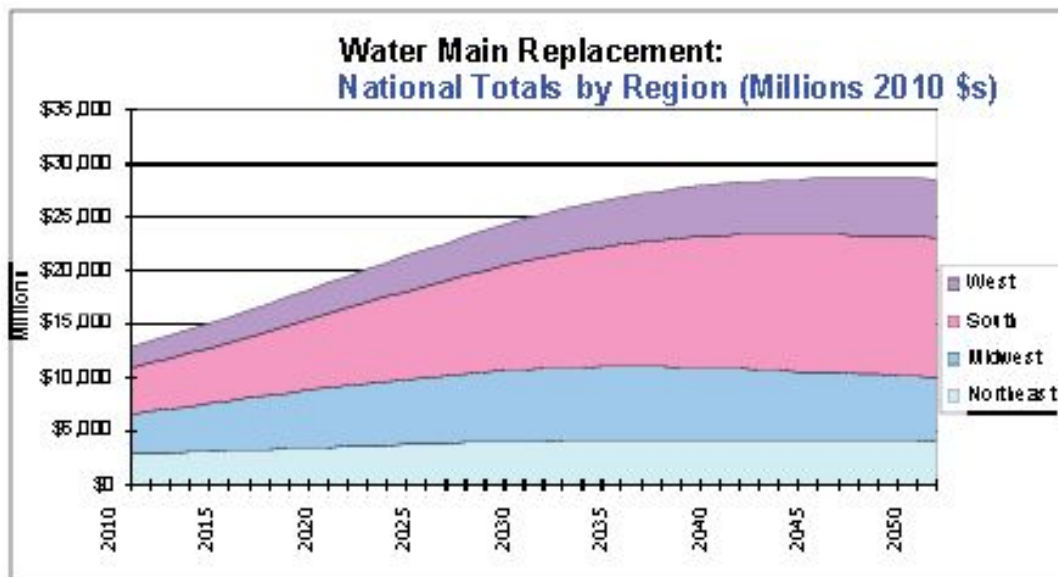
3.1.2.1 National infrastructure overview

It is estimated that there are more than 1 million miles of water mains in the United States. Some pipes date back to the Civil War era, the oldest constructed of wood. Buried out of sight, the conditions of most of these are unknown until there is a problem or a water main break. There are 240,000 water main breaks per year in the United States. Estimated water loss from distribution systems is 1.7 trillion gallons per year at a cost of \$2.6 billion per year (USEPA 2007). The American Society of Civil Engineer's (ASCE's) Infrastructure Report Card gives drinking water a "D." ASCE further identifies an annual shortfall of at least \$11 billion needed to replace facilities at the end of their useful life and to comply with existing and future water regulations (ASCE 2013a).

The life spans of piping assets making up water infrastructure systems can vary. Pipes have life cycles ranging from 15 to over 100 years depending on the material and the environment. Approximately 4,000 to 5,000 miles of drinking water mains are replaced each year; however, this is inadequate to rehabilitate the systems reaching their end of life (USEPA 2013). Investment needs for drinking water infrastructure over the next 25 years are more than \$1 trillion nationwide (AWWA 2012a). This includes both the cost to repair existing systems and to expand to meet the needs of growing population (Figure 3).

Water system losses also carry a heavy energy burden. Southern California Edison estimates that energy savings in the range of 1,020,125,599 KWh/year are possible by addressing water system leaks. That amounts to about 26% of California's power generated by thermoelectric coal plants in 2008 (Sturm et al. 2010).

Figure 3. US water main replacement costs by region.



Source: AWWA 2012a

Many state legislatures are requiring utilities to conduct regular water audits. Texas and Tennessee are among them. The Delaware River Water Basin (DRWB) adopted a number of water conservation policies that are mandated for water purveyors in this four-state region (Delaware, Pennsylvania, New York, and New Jersey). Among these is Resolution 87-6 that requires systems of over 100,000 gpd to develop and undertake leak detection and repair programs (State of New Jersey 2011).

3.1.2.2 Army infrastructure overview

Historic surveys of installation drinking water distribution systems report 9% unaccounted-for water where it was possible to measure (Bandy and Scholze 1983). Water sustainability assessments of 10 Army installations (completed in FY11) estimated water loss at 15%, the target established by the AWWA for unaccounted-for water. This assumption was made due to the lack of metering and monitoring of drinking water systems at most of the study sites (Jenicek et al. 2011). It is likely that leakage rates on post are the same as those for similar-aged systems in local communities, where water loss in excess of 30% is reported. Even the best-in-class standards are 7%, but most utilities are losing from 15 to 25% of their water (Rafter 2013).

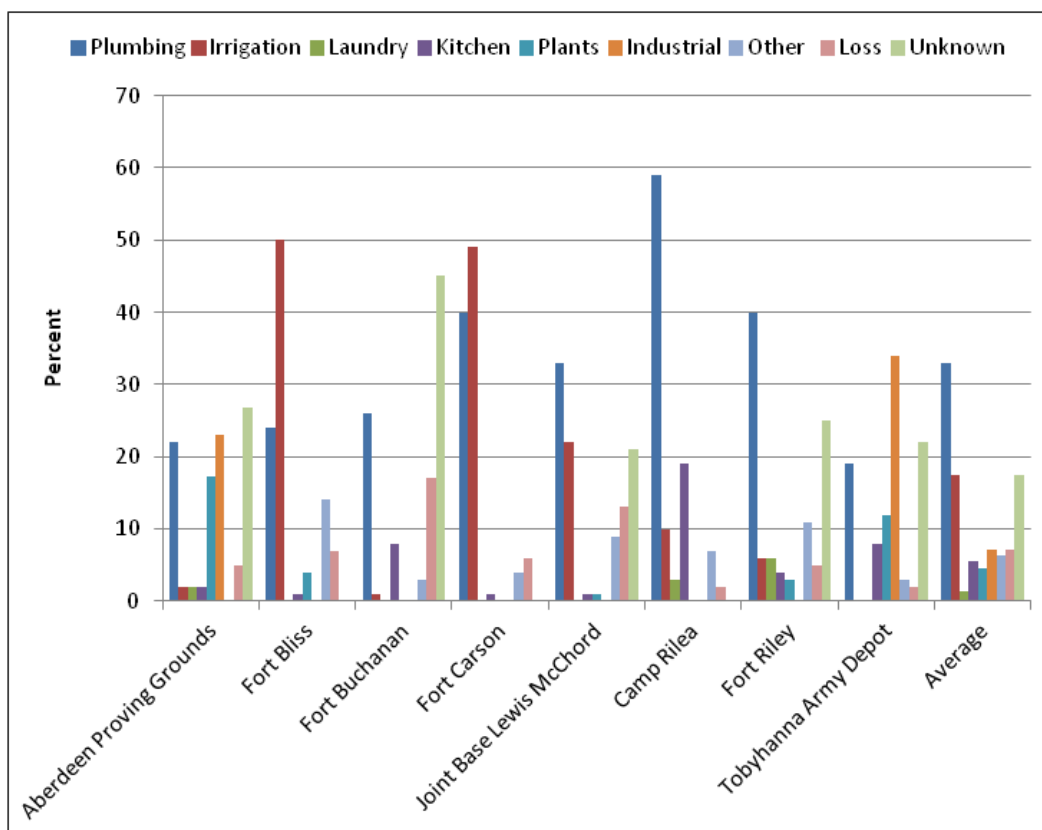
More recent surveys of the 10 NZW installations included detailed building audits to create an installation-wide water balance. The total installa-

tion water demand as measured by the main meter, located at the point of purchase or the post drinking water treatment plant, was disaggregated by end-use. In Figure 4, which shows the results for these surveys, the term “Loss” refers only to known losses. However, most installations had *unknown* water end-use exceeding 20%. It is likely that at least part of this end-use category is also water loss.

3.1.3 Drinking water distribution system recapitalization

Planning for water distribution system renewal requires credible estimates of where, when and how much system repair is needed. Managing existing infrastructure efficiently to manage costs of repair and replacement is the driver for determining a desirable rate of leak detection. Asset management can be accomplished at the available level of funding.

Figure 4. Water consumption for eight NZW installations.



Compiled from data in PNNL (2012a-h).

Detecting leaks that cannot be immediately repaired is a poor use of resources. A proactive program of planned incremental system rehabilitation goes hand-in-hand with periodic leak detection of the most vulnerable water mains. However, the knowledge of infrastructure condition through periodic leak surveys is valuable in and of itself by providing data required for a reliable estimate of water end-use.

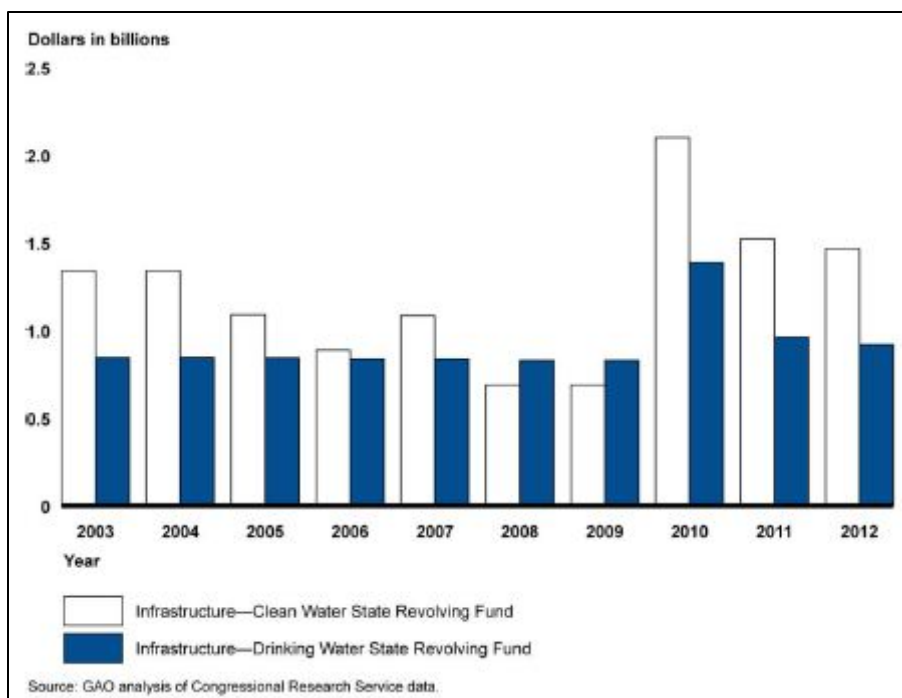
System monitoring and repair must start with a plan that prioritizes high risk and critical survey zones while establishing a survey routine that encompasses the entire system. This should include routine checks of older or higher risk pipes. Comprehensive leak detection must be done with a combination of detection technologies intended to reduce survey time and address the varied inventory of pipe systems. Similarly, selection of pipe repair technique will be based on location and pipe status. The key to water distribution system monitoring and maintenance is vigilance and proactive measures.

3.1.3.1 Determining infrastructure renewal needs

The AWWA developed methods for estimating investment costs to maintain and expand drinking water systems for the entire United States. These methods took into account region of the country, size of distribution system, and piping material. Geographic regions tend to share growth patterns and piping types thereby possessing water systems of similar age distribution. The analysis includes seven piping materials in three diameters and considers pipe inventories dating back to 1870. Finally, this information was incorporated into the Nessie Model™ that embodies pipe failure probability distributions based on input from operating utilities. Nessie™ produced a national-level analysis of the cost, timing, and location of investments required to maintain current levels of service (AWWA 2012a). Nessie™ is also incorporated into AWWA's Pipe Need Predictor modeling software, an interactive tool that can be used to help determine where to replace, when to replace, how much replacement or expansion is required, and the costs of replacement for a particular utility.*

* The Nessie™ recommendations are based on a user-specified mix of pipe types, pipe age, system size, and location.

Figure 5. Ten year trend for SDWA revolving loan fund.



Source: US GAO 2013

3.1.3.1 Funding water infrastructure projects

Historically, water utilities have relied on the Federal government to finance major infrastructure projects. One source of Federal funding is the SDWA, State Revolving Loan Fund (SRF) appropriations. State matching of 20% of the Federal grant money is required. States then provide low- or no-interest loans to communities or utilities. These funds have markedly decreased with Congressional appropriations declining, financing only 8% of identified needs (Figure 5). The current trend is towards state and local governments financing most of the work; this trend is expected to continue (ASCE 2013a, USGAO 2013). About 70% of communities finance water infrastructure projects with municipal bonds and other forms of debt (AWWA 2012b).

To address this problem, ASCE (2013a) recommends:

- raising awareness for the true cost of water
- reinvigorating the SRF program under the SDWA by reauthorizing minimum Federal funding of \$7.5 billion over 5 years
- eliminating the state cap on private activity bonds for water infrastructure projects

- exploring the potential for a Water Infrastructure Finance Innovations Authority (WIFIA)
- establishing a Federal Water Infrastructure Trust Fund.

3.1.3.2 Case study: Chicago, IL

Chicago initiated what Mayor Rahm Emanuel calls the “largest public works initiative by any city in the country” by committing to overhaul 900 miles of the city’s 4300 mile network of water pipes over the next decade. In recent years, the city has replaced some 30 miles of pipe a year. However, this pace was found to be inadequate to address the problem, so it has since more than doubled. During the time period from 1890 to 1920 the city laid 75 miles of mains each year that were anticipated to last no longer than a century. It is the 100-year old lines that are being replaced. The city is raising water and sewer rates to fund this accelerated program, creating construction jobs at the same time that the payroll of the city’s Water Management Department has been cut (Mihalopoulos 2011).

3.1.4 Leak detection surveys

Proactive detection through methodical field work is the best solution for reducing water loss. Several methods and technologies are available to detect and control leaks.

Acoustic detection is the most used and diverse method for detecting leaks. Hydrophones, leak noise loggers, leak noise correlators, streaming cable inline acoustic leak detectors, free-floating inline acoustic leak detectors, acoustic fiber optics, and/or electromagnetic field detection can be used to detect the sounds that pipe leaks make.

Thermal detection uses infrared radiation to find temperature differences in the surrounding ground caused by water saturation from leaking water. Electromagnetic systems that have been used to detect buried utilities can also be used to detect leaks. Ground penetrating radar (GPR) locates subsurface leaks using a rolling unit going back and forth across the pipeline.

3.1.4.1 Data availability from satellite imagery

Finally, the use of chemical tracers relies on the method of introducing a unique gas or liquid to a system. Leaks are detected if the chemical is

found outside the system. Tracer gas needs pipelines to be dewatered whereas trace liquids are added to the water. It is recommended that installation staff consult with the local drinking water regulatory agencies before implementation of liquid tracers (USEPA 2010a).

3.1.4.2 Case study: Tobyhanna Army Depot

Tobyhanna Army Depot (TYAD) has an active leak detection program. The program was initiated in 2009 under a contract administered by the USACE Baltimore District. A contract was awarded to Weston Solutions, Inc. to perform a drinking water system leak/loss study at TYAD. Directorate of Public Works (DPW) personnel evaluated the cost effectiveness of the program using the National Institutes of Science and Technology (NIST) BLCC 5.3-11 life cycle costing system. The project showed an initial Savings-to-Investment Ratio (SIR) of 2.27 and an Adjusted Internal Rate of Return (AIRR) of 11.79%.

The TYAD water distribution system is approximately 85,000 linear feet of water mains, with diameters ranging in size from 1 to 14 in. The system is primarily cast iron, but also contains copper, galvanized steel, and polyvinyl chloride (PVC) pipe. Approximately 30% of the water flow at TYAD is metered, primarily on distribution mains leaving TYAD, high water use industrial processes and all source water mains.

The Weston contract included a comprehensive acoustic leak detection survey, which occurred in September 2009. This survey detected water loss of approximately 90,000 gallons per day (gpd), which amounts to 26% of the average daily water use, in six leaks. While the cost of the lost water might seem insignificant using current valuation methods, the financial impacts of water risks—reduced allocation, remediation, and water shortages—are more costly than direct and indirect water costs combined (Clere 2013). In addition, Weston recommended a series of BMPs to minimize future leaks (USACE 2010). Based on the contracted cost of \$88,000, the initial TYAD leak detection survey came in at \$1.04/ft of water main.

Subsequent to the Weston survey, TYAD installed a leak detection system in April 2010 through another contract. This contract included training in the use of the leak detection equipment, which remained in use at the time of this report (USACE 2010) (Appendix C).

The leak detection system consists of acoustic loggers to listen for leak noises transmitted through the pipes, drive-by data downloading equipment to collect noise data from loggers, a leak correlator to pinpoint potential leaks after loggers indicate leak noises in an area, and a laptop computer to display and analyze data. Acoustic loggers are mounted on exposed valves, hydrants, or meters and can isolate leaks in piping runs between these components. The electronic correlation system has an accuracy of 1 meter and estimates leaks in gpd.

3.1.4.3 Case study: Fort Carson

Fort Carson used USACE to contract with Kenneth Hahn Architects for a water leak detection assessment in September 2011. The survey was performed by Wachs Water Services. The engineering evaluation and analysis was performed by Olmsted & Perry Consulting Engineers.

The Fort Carson water distribution system is approximately 285,000 linear feet, about 54 miles of water mains. The material types used in the water system piping include ductile iron, two-bolt cast iron, cement, asbestos cement, PVC, and HDPE. Fort Carson has 53 sub-meters on post accounting for approximately 11% of the water flow. Irrigation meters account for 27% and family housing is one of the larger sub-metered accounts (PNNL 2012).

The leak survey occurred from 19-22 March 2012 on four priority areas of Fort Carson's water distribution system, encompassing 16 miles, or about 30% of the older water system. Pipe diameters in the surveyed areas ranged in size from 4 to 12 in. Leak sounding was conducted on fire hydrants and water valves in these areas. This amounted to 440+ accessible listening points (171 hydrants and 224 valves) with an average distance of 201 ft between points. Surveyors also used ground microphone sounding to find leaks that were not at listening points. This survey did not include correlation.

The leak survey identified 13 areas with leaks, including five valve leaks, six fire hydrant leaks, and two mainline/joint leaks. All of the leaks were categorized as Class 1, indicating that they need to be fixed when resources are available. Only two of the leaks were surfacing at the time of the survey. The leakage was estimated to be 40 gallons per minute (gpm) (between 1 and 6 gpm/leak) for a total water loss of 57 kgal/day (Kenneth Hahn Architects 2012) (Appendix D).

Based on the contracted cost of \$42,000, the initial Fort Carson leak detection survey came in at \$0.49/ft of water main. The contractor provided cost estimates for repair of the 13 detected leaks along with a set of general recommendations to improve operation of the water distribution system. The estimated repair cost was \$116K while the cost of lost water (21 MG/year) was estimated at \$31K using a water price of \$1.50/kgal. Based on current pricing (\$2.71/kgal winter and \$5.12/kgal summer), the cost of lost water would be significantly higher resulting in a faster payback (PNNL 2012).

Fort Carson's base maintenance contractor performed inspections of the distribution system during the leak repair process, and determined that the leakage rate was probably half that estimated by Hahn/Wachs. Due to Fort Carson's high water cost, these piping repairs remain cost effective (Guthrie 2013).

3.1.5 Alternate means of assessing water loss

In the absence of a regular program of leak assessment, there are other methods to estimate water loss. Comparison between water withdrawals/supply and sewage production will provide a starting point for this calculated estimation. This value will need to be evaluated taking into account:

- groundwater inflow to the outgoing sewer lines (gain)
- extraneous water inflow to the sewage treatment plant (gain)
- stormwater overflow (gain)
- line flushing, including fire hydrants (loss)
- water lost through evaporation (loss)
- unmetered ILA water (loss)
- swimming pools (loss)
- special uses e.g., unique training, dust suppression, wash racks (loss)
- unmetered bulk water use e.g., water buffalos, contractors (loss).

The limited number of water meters on Army facilities makes this method a challenging endeavor. Detailed analysis of base-wide metered data, taking into account changes in population and climate, could reveal water use trends that would illuminate major leaks. The installation of a few water meters at strategic locations in the system or at the supply points for discrete supply zones could provide more detailed information for such an analysis.

3.1.6 Potential Army data sources

The Army's OACSIM maintains a number of centralized databases to streamline the collection and analysis of infrastructure data. These are accessible through the Installation Management Application Resource Center (IMARC) web site, <http://www.acsim-apps.army.mil/>. Systems available through IMARC are:

- Army Energy and Water Reporting System (AEWRS)
- Army Mapper
- Army Stationing and Installation Plan (ASIP)
- Headquarters Installation Information System (HQIIS)
- Integrated Facilities System (IFS)
- Installation Status Report (ISR)
- Real Property Planning and Analysis System (RPLANS)
- Solid Waste Annual Reporting for the Web (SWARWeb).

The following sections describe and discuss select database and information management systems, from IMARC and other sources, which could support collection of data for and evaluation of progress towards meeting the requirements of candidate water metrics.

3.1.6.1 Army Energy and Water Reporting System (AEWRS)

AEWRS is the automated system used by the Army to facilitate annual reporting of energy and water consumption and progress towards goals to the Office of the Secretary of Defense (OSD). AR 420-1, *Army Facilities Management* contains reporting responsibilities, requirements, and procedures for using AEWRS. The AEWRS Users Manual (DA 2012b) gives detailed instructions for the use of AEWRS.

Installation water data is manually input to AEWRS quarterly. Water use must be reported whether it is purchased water or supplied from installation surface water and wells. Cost of in-house or privatized utility systems should be calculated based on methods in AR 420-41, *Acquisition and Sales of Utilities Services* (DA 1990). Newer guidance can be found in *Interim Guidance on the Calculation of Rates for the Sale of Utilities Services and Utilities Contracts Invoicing/Billing* (ACSIM 2013). Data are input in five categories including potable, industrial, landscaping, agricultural, and alternative nonpotable water (previously termed recy-

cled/reclaimed). Reporting requirements for industrial, landscaping, and agricultural were added to the system in FY 2011. The standard unit of measure for water is millions of gallons (MGAL).

Annual factors in AEWRS include building square footage, which is used to calculate potable water intensity, a key metric for conservation. Square footage of buildings is imported to AEWRS from HQIIS. However, installations that do not report data into HQIIS must input building square footage data manually into AEWRS. Data imported from HQIIS excludes commissaries, leased buildings, where Army does not pay for the utilities, privatized housing (Residential Communities Initiative [RCI]), and non-government (non-Federal) tenants. National Guard Federal support codes determine the percent of each building's square footage counted (DA 2012b).

Command and component managers review their installations' data by quarter, validate the data, and certify/lock the data as complete and accurate. Data that is not validated and locked by the commands/components will none the less be locked a month and a half after the last day of each quarter (DA 2012a).

3.1.6.2 Headquarters Installation Information System (HQIIS)

The Headquarters Installation Information System (HQIIS) is the Army's enterprise level comprehensive information repository and the Army's authoritative source for real property installation, site, and base data. HQIIS interfaces with OSD's Asset Registry system and key Army systems. It is populated from the following installation level real property databases: IFS, Planning Resource Infrastructure Development and Evaluation (PRIDE), Real Estate Management Information System (REMIS), and Rental Facility Management Information System (RFMIS).

Each real property facility category is assigned a category code (CATCD), a five digit numerical code that is used to identify the function or usage of a specific type of facility (DA 2004, DA 2006). Collectively, these data are referred to as real property categories. Each real property facility category, in addition to CATCD, is also associated with facility type, description, measurement units, facility analysis category (FAC), facility category group (FCG), Department of the Army Staff facility category proponent, general ledger account (GLAC), and the investment category. The four types of facil-

ities included in real property are: (1) land; (2) building; (3) utility—distribution system, commodity source or collection point—measured in capacity; and (4) structure—anything not classified as building, utility system, or land. Within HQIIS, the following CATCDs are used to identify water infrastructure:

- 84110 Water Treatment Plant
- 84125 Filter Plant Facility
- 84130 Water Well, Potable
- 84141 Pump Station, Potable
- 84150 Chlorinator Facility
- 84210 Water Distribution Lines, Potable
- 84215 Supply Main, Potable
- 84330 Fire Protection System, Nonpotable
- 84510 Water Distribution Lines, Nonpotable.

Table 2 lists NZW installation potable water systems indicating the total system length and the cost to conduct leak detection assessment from HQIIS information.

3.1.6.3 Army Mapper

Army Regulation 115-13, Climatic, Hydrological, and Topographic Services Installation Geospatial Information and Services (March 2013) requires submission of geographic information system (GIS) data quarterly. The Army Mapper System is the automated means for submitting GIS data (OACSIM 2013b). The Army's enterprise GIS includes:

- The *Web Map Viewer*, a web-based interactive mapping tool providing basic viewing and querying of common data for all integrated installations
- *Desktop Tools*, commercial GIS and Computer-Aided Drafting and Design (CADD) software available through Citrix
- A *Data Repository*, secure and robust data architecture to support managed maintenance and archival of standardized installation data.

The Army Mapper does not communicate with the BUILDER™ Sustainment Management System (SMS) (see section 3.1.8.3).

Table 2. NZW installation potable water systems*

Installation	Potable Water Distribution Systems (CatCodes 84210 and 84215)			
	System Length	25%	\$/25%*	\$/25%**
<i>Net Zero Water Installations</i>				
Aberdeen Proving Ground	1,036,324'	259,081'	\$269,444	\$126,949
Fort Bliss	2,083,123'	520,780'	\$541,611	\$255,182
Fort Buchanan	170,978'	42,744'	\$44,453	\$20,944
Fort Carson	285,000'	71,250'	\$74,100	\$42,000 ⁺
JBLM	1,847,011' [†]	461,752'	\$480,222	\$226,258
Camp Rilea	56,737'	14,184'	\$14,751	\$6,950
Fort Riley	1,227,421'	306,855'	\$319,129	
Tobyhanna Army Depot	85,000'		\$88,000 [‡]	
<i>Other Installations</i>				
Fort Benning	1,086,052'	271,513'	\$282,373	\$133,041
Fort Bragg	3,053,005'	763,251'	\$793,781	\$373,992
Fort Campbell	1,359,344'	339,836'	\$353,429	\$166,519
Fort Detrick	211,614'	52,903'	\$55,019	\$25,922
Fort Drum	1,105,119'	276,279'	\$287,330	\$135,376
Fort Hood	2,035,361'	508,840'	\$529,193	\$249,331
Fort Stewart	1,089,535'	272,383'	\$283,279	\$133,467
Fort Polk	3,307,546'	826,886'	\$859,961	\$405,174
Army Total (includes NGB)	70,016,206'	17,504,051'	\$18,204K	\$8,577K
* Based on the cost of \$1.04/ft from Tobyhanna Army Depot, PA ** Based on the cost of \$0.49/ft from Fort Carson, CO † Includes potable water distribution system for the Fort Lewis portion of JBLM only. ‡ Tobyhanna cost is for conducting a leak assessment on the entire installation. + Fort Carson cost is for conducting a leak assessment on 30% of the water distribution system.				

The Spatial Data Standards for Facilities Infrastructure and Environment (SDSFIE) for water lines are defined by the Army's Installation Geospatial Information and Services (IGI&S) Program that is led by ACSIM's Operations Division of the Operations Directorate (DAIM-ODO). This includes pipelines, supply mains, pumps, valves, and fire protection systems that are combined with potable water networks. The CATCDs included in this layer are 84210, 84215, 84330, and 84510 (US Army IGI&S 2010). Among other requirements in SDSFIE is that the water line geospatial data layer must align with HQIIS. Data updates to the layer will reflect existing conditions, with a minimum update interval of a year.

* System parameters were obtained from installation water managers or from the HQIIS system.

The Common Installation Picture (CIP) is the standard set of data that each installation must maintain. The CIP currently does not include utility lines; however, this is currently being updated (September 2013). Historically there has been some concern about the sensitivity of utility data (Nicchitta 2013).

Another initiative related to GIS data is linear segmentation, which is an OSD requirement. Linear assets include roads and utility systems such as water piping, electrical distribution lines, and gas piping. The goal of this program is to accurately capture the number of linear networks. OSD does not require UP contractors to adhere to linear segmentation requirements. Army guidance is currently being developed (Nicchitta 2013).

Water distribution systems that fall under UP are not required to comply with the Army Mapper mandate. No two UP contracts are the same. Some contracts may require updated GIS drawings. However, they may not require SDSFIE format and may just consist of a CADD drawing. Likewise, RCI and Privatized Army Lodging (PAL) contracts also differ and may or may not include requirements to maintain GIS and provide this data for the Army Mapper System (Nicchitta 2013).

The US Army Reserve and the National Guard Bureau have their own GIS programs that feed data into the Army Mapper. They have their own program manager separate from ACSIM's. Each of the NGB's 54 reporters provides CIP data on a periodic basis that is centrally loaded into Army Mapper. This interval is becoming shorter with the goal being quarterly Army Mapper updates the same as the active Army (Argentieri 2013)

3.1.6.4 Army installation GIS systems

Although Army Mapper is the official system in place for managing GIS data, installations often maintain their own systems. Table 3 lists the results of the following informal query about such systems:

- What software are you using for your GIS?
- What data layers do you have? There should be a utilities layer for water.

Table 3. Existing GIS systems at NZW installations.

Installation	GIS System	Is there a potable water data layer?
Aberdeen	ESRI ArcGIS 10 and Army Mapper	Yes
Bliss	Fort Bliss Water maintains GIS	
Buchanan	N/A	N/A
Carson	MicroStation/Oracle Spatial and Army Mapper	yes
JBLM	ESRI ArcMap 10	yes
Rilea	Maintain data locally; CIP through NGB	
Riley	Converting from CADD to GIS; also, Army Mapper	yes
Tobyhanna	ESRI ArcGIS 10 and Army Mapper through AMRDEC	yes
Detrick	Local GIS and Army Mapper	

3.1.6.5 BUILDER™ Sustainment Management System (SMS)

The BUILDER™ SMS is used to manage building requirements at the component level for improved condition and readiness reporting and to support sustainment, restoration, and modernization (SRM) decisions. The BUILDER™ process starts with automated download of real property data. This is followed by a detailed system inventory, accomplished through site inspections, to identify components and their life cycle attributes such as age and material. BUILDER™ is being widely adopted across the DOD and is in varying stages of adoption by the Marine Corps, Navy, Air Force, Army, Defense Logistics Agency, and Tri-Care Medical Agency.

Facility information maintained in BUILDER™ includes plant replacement value. System level inventory information includes component type, quantity, and year installed. Each component also carries a unit replacement cost and expected service life based on construction industry standard data. These data are used to calculate the age and initial estimated remaining service life as well as an obsolescence index for each component. BUILDER™ can also be used to perform functionality assessments to evaluate user requirement changes, compliance, and obsolescence issues (ERDC 2013).

BUILDER™ contains a condition life cycle and prediction analysis capability that can draw on condition assessment information from the Army Installation Status Report for Infrastructure (ISR-I). Building systems condition information from BUILDER™ and ISR-I can be incorporated into each of the systems, based on the latest physical observations of the building and each building component. This concept was demonstrated in an

ACSIM Installation Technology Transition Program (ITTP) project (Figure 6) (Grussing 2012). The current focus of BUILDER™ is building stock. However, there is interest in adding utilities to the system.

3.1.6.6 General Fund Enterprise Business System (GFEBS)

The GFEBS is a web-based financial management system that standardizes and streamlines financial business processes. GFEBS integrates different modules to access that same database and use the same data, for example, financial and cost data associated with real property. There are 83 financial systems that will be subsumed by GFEBS and another 210 systems under evaluation. GFEBS is intended to increase budgetary efficiency while eliminating legacy systems. Incremental fielding of GFEBS R1.3 launched in April 2009 (ASA[FM&C] 2009).

Figure 6. Facility-level SRM planning information for an Admin Building.

Building Level Info				System Level Info						
Bldg #: 1010 Bldg Name: Q Rating Example Catcode: 61010 - Administrative Office Building Type: Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms Current Status: Active Type: Permanent Area: 19,144 SF Year Constructed: 1979 Year Renovated: 1999 Floors: 2 PRV: \$3,034,000 Bldg Obsol Index (BFI): 66 Bldg Cond Index (BCI): 79				System	CRV	SFI	SCI			
				A10 Foundations	\$117,000	96	95			
				B10 Superstructure	\$292,000	95	94			
				B20 Exterior Closure	\$298,200	81	74			
				B30 Roofing	\$81,100	94	95			
				C10 Interior Construction	\$250,700	75	80			
				C20 Staircases	\$3,500	82	80			
				C30 Interior Finishes	\$276,900	62	66			
				D10 Conveying Systems	\$78,000	63	60			
				D20 Plumbing	\$128,500	58	62			
				D30 HVAC	\$559,500	66	77			
				D40 Fire Protection	\$86,000	95	95			
				D50 Electrical	\$361,450	78	83			
Component Level Info										
System	Component	Type/Description	Qty (UM)	Installed Year	Replace Value \$	Age	Obsol Index	Cond Index	RSL Initial	RSL Adjusted
A10 Foundations	A1010 Standard Foundations	Strip Footings	420 (LF)	1979	\$23,000	32	100	95	118	102
	A1030 Slab on Grade	Plain/Reinforced	10,000 (SF)	1979	\$84,000	32	95	88	43	34
B10 Superstructure	B1010 Floor Construction	CP Concrete Beam and Slab	10,000 (SF)	1979	\$231,000	32	95	95	43	42
	B1020 Roof Construction	Steel Deck on Beams and Bar Joist	10,000 (SF)	1999	\$81,000	12	96	88	18	14
B20 Exterior Closure	B2010 Exterior Walls	Concrete Block	10,000 (SF)	1979	\$126,000	32	90	88	28	25
	B2020 Exterior Windows	1st Floor - Steel Windows	38 (EA)	1979	\$60,000	32	75	81	13	6
	B2020 Exterior Windows	2nd Floor - Steel Windows	54 (EA)	1979	\$90,000	32	75	81	13	6
	B2030 Exterior Doors	Glazed Doors	4 (EA)	1979	\$15,000	32	75	88	13	23
	B2030 Exterior Doors	Steel Doors	3 (EA)	1979	\$7,200	32	75	80	13	16
B30 Roofing	B3010 Roof Coverings	Built-Up	10,000 (SF)	1999	\$79,000	12	94	88	16	4
	B3020 Roof Openings	Hatches	1 (EA)	1999	\$2,100	12	96	80	28	15
C10 Interior Construction	C1010 Partitions	1st Floor - Concrete Block	4,800 (SF)	1979	\$61,000	32	95	95	43	42
	C1010 Partitions	2nd Floor - Concrete Block	5,400 (SF)	1979	\$68,000	32	95	95	43	42
	C1020 Interior Doors	1st Floor - Wood Door/Metal Frame	35 (EA)	1979	\$44,500	32	64	71	8	10
	C1020 Interior Doors	2nd Floor - Wood Door/Metal Frame	48 (EA)	1979	\$58,000	32	64	71	8	10
	C1030 Fittings	1st Floor - Toilet Partitions	6 (EA)	1979	\$9,600	32	1	30	0	0
	C1030 Fittings	2nd Floor - Toilet Partitions	6 (EA)	1979	\$9,600	32	1	30	0	0
C20 Staircases	C2010 Stair Construction	Stairs	2 (EA)	1979	\$3,500	32	82	80	18	18
C30 Interior Finishes	C3010 Wall Finishes	1st Floor - Wall Tile	700 (SF)	1999	\$8,000	12	96	95	28	25
	C3010 Wall Finishes	2nd Floor - Wall Tile	750 (SF)	1999	\$8,500	12	96	95	28	25
	C3020 Floor Finishes	1st Floor - Carpet Tile	8,000 (SF)	1999	\$50,000	12	1	10	0	0
	C3020 Floor Finishes	1st Floor - Composition Sheet	1,500 (SF)	1999	\$15,000	12	78	71	6	4
	C3020 Floor Finishes	1st Floor - Ceramic Tile	350 (SF)	1999	\$3,700	12	99	95	38	33
	C3020 Floor Finishes	2nd Floor - Carpet Tile	8,000 (SF)	1999	\$50,000	12	1	10	0	0
	C3020 Floor Finishes	2nd Floor - Composition Sheet	1,400 (SF)	1999	\$14,000	12	78	71	6	4
	C3020 Floor Finishes	2nd Floor - Ceramic Tile	350 (SF)	1999	\$3,700	12	99	95	38	33
	C3030 Ceiling Finishes	1st Floor - Acoustical	10,000 (SF)	1999	\$62,000	12	84	88	8	9
	C3030 Ceiling Finishes	2nd Floor - Acoustical	10,000 (SF)	1999	\$62,000	12	84	88	8	9

Source: Grussing 2012

One function of GFEBS is to identify facility maintenance requirements through integrated asset valuation and depreciation. The desired outcome is an improved and standardized process for planning and performing maintenance on real property and equipment. One example of how GFEBS populates other data systems is by providing real property square footage to the HQIIS system. Installations use the GFEBS-RP module. HQIIS sends data to other systems such as AEWRS. AEWRS rolls up installation data to provide Army input for reporting to DOD.

3.1.7 Application to National Guard activities

For the Oregon National Guard, GIS data are maintained locally. Only CIP data are submitted through the National Guard Bureau approximately bi-ennial, though the target interval is quarterly submission. In the Army Mapper, the National Guard CIP data is aggregated into one service called “Army National Guard” though the data is sent by each of 54 reporting units to the headquarters NGB for aggregation. The Army National Guard folder contains Installations and Environmental data that is of limited scope. CIP is a relatively small subset of the total Oregon National Guard GIS data holdings (Anderson 2013, Argentieri 2013).

3.1.8 Discussion and recommendations

Developing a candidate metric for leak detection requires knowledge of the age and condition of Army drinking water infrastructure so as to optimize leak detection resources by focusing on systems that can be repaired if leaks are discovered. The following recommendations are made:

- Identify recapitalization requirement for installation water distribution systems. Use BUILDER™ and ISR-I to prioritize both leak detection surveys and water infrastructure upgrades.
- Identify GIS systems currently in use on installations.
- Assess the ability of Army Mapper to support the data requirements of this metric. Identify the required data layers and the reporting status/accuracy across installations.
- Include a leak detection requirement in the Annual Work Plan (see Department of the Army Pamphlet [DA Pam] 420-06 [HQDA 1997]).
- Add additional AEWRS reporting fields that are similar to Energy Manager Data Entry of BMPs, Water Management Plan, Energy Personnel, Energy Savings Performance Contract (ESPC) contracts, Utility

Energy Service Contract (UESC) projects, and Energy Conservation Investment Program [ECIP] projects).

3.1.9 Potential operational definition

Measure Number: 8-3.1.1

Owner: DASA(E&S)

Major Objective: Reduce potable water consumption intensity at permanent installations (8.1)

Army Campaign Plan Objective: Achieve Energy Security and Sustainability Objectives (8.0)

Description: Potable water distribution system linear feet assessed for leaks.

Lag/Lead: Lag

Frequency: Quarterly

Unit Type: Percent

Preferred Trend: Down

Formula: Total amount of linear feet of potable water distribution system assessed for leaks in a quarter/the total linear feet.

Data Sources: Total linear feet of potable water distribution system is available through the ACSIM Headquarters Installation Information System (HQIIS).^{*} Another potential source is GIS data layer for potable water, available through the Army Mapper System. The linear feet of potable water distribution system surveyed for leaks each year is also available from the installation DPW.

Data Quality: Variable; UP contractors are not required to provide GIS data for the Army Mapper System.

Data Collector: HQIIS and Army Mapper are automated systems that are already populated by installation personnel. Installation-specific information about potable water system inspection would need to be incorporated into an automated system or collected manually.

Baseline: None

^{*} available at <https://www.acsim-apps.army.mil/secure/hqiis/>

Target: Fiscal Year 2013: xx%

Target by Calendar Quarter: 2013 1stQ xx%; 2ndQxx%; 3rdQxx%; 4thQxx%

Target Rationale: A leak detection measure is needed to support infrastructure water efficiency. Consistent surveys are in line with a regular program of investment in infrastructure recapitalization.

Strategies:

Cost: TBD

Accuracy: HQIIS draws data from GFEBS. Army Mapper data are updated quarterly by installation staff.

Validity: Using percent of potable water line inspected directly addresses water loss.

Reliability: A leak detection survey will be accurate at a point in time after which new leaks can occur.

Relevance: The measure draws on data sources that may not be consistent across the Army e.g. UP contractors and NGB.

3.2 Gallons per person per day (candidate metric 8-3.2.2)

Water metrics used to capture demand trends throughout military installations are limited to one metric that measures water intensity per square foot. Although the calculation is straightforward, dividing the overall real property square footage by metered water at the installation level may lead to misrepresentation of how an installation actually uses water. A metric of water per capita may provide better insight into how an installation uses water over time as it could be tied to the number of actual users present and not a spatial measurement that does not change while personnel are deployed. With any metric there will be outliers such as installations with water intensive uses, such as Tobyhanna Army Depot with industrial or Aberdeen Proving Ground with research labs. However, calculating a per-capita metric, if possible, could begin to provide insight on how population change and personal use affect water demand at most Army installations thereby creating a more accurate baseline from which future conservation measures could be focused or designed. This section explores options in providing reasonable water metric with existing tracking resources available within the Army, AWWA, and US Census data.

3.2.1 Level of confidence

Creation of a per-capita water metric is meant to capture the amount of water the average user on an installation consumes while on the installation. The average user includes not only the personnel living on the installation, but all active duty, contractors, civilians workers, dependents, and retirees who may visit the installation. With a population that has the potential to spend anywhere from 1 to 24 hours on the installation, a calculating a per-capita metric of an average user with a high confidence level (95% or higher representation of the applicable population) on any one day is unlikely. The intent instead is to create the “80%” solution; or something that gives the user a guide or a general baseline from which to begin their own efforts towards improving efficiency on their installation. The source of this general baseline is likely to come from populations calculated from ASIP and DEERS data.

3.2.2 ASIP and DEERS

The official Army population is tracked through ASIP, which is used for long-term planning at the installation level. It is a quarterly updated population number that includes official Tables of Distribution and Allowances (TDA) and Modified Table of Organization and Equipment (MTOE) authorizations, contractors on post, and other tenant personnel. Depending on the installation these numbers are collected by the Plans, Analysis, and Integration Office (PAIO) monthly or quarterly, and then are updated to the central ASIP database. The ASIP data feeds into DEERS,* from which IMCOM creates an annual report. The DEERS report that comes annually from IMCOM provides various metrics describing the Army based on algorithms pulling from several data sources combined with its personnel system. The overall report from IMCOM justifies funding levels to various installations based on their personnel status and needs.

One such metric, which is often at odds with the ASIP data and the PAIO analysis, is the population served on the installation (Dudek 2012). The DEERS system tracks anyone with a Common Access Card (CAC) by zip

* DEERS is the main personal identification tracking system with personal data of Active, Reserve, and civilian members including dependents. The military's TriCare health care system's personal database is tied to DEERS to help manage its health care eligibility.

<https://g1armg.army.pentagon.mil/systems/DEERS/pages/default.aspx>

code. Based on address location near an installation, it is assumed at the IMCOM level that anyone in a zip code that is within 40 nautical miles of an Army installation is part of the served population for that installation. When the radial distance overlaps with nearby installations, it is up to ASIP to assign respective zip codes and their respective CAC population holders to an installation. The assignment is based on purely on relative geographic distance and not on known commuting patterns (Ryman 2013). The assignment is only for ASIP accounting. It does not affect anyone's actual access to an installation, but it does prevent double counting of close proximity installations in such as areas surrounding Washington DC. The population served at an installation includes not only the stationed personnel, but also all the retired, reserve, dependents, and guard personnel. ASIP does not take into account the transportation or commuting habits of the region when assigning zip codes and therefore it is difficult to know how accurate surrounding population numbers are in estimating the actual population served per installation. Thus the reason it sometimes does not appear accurate to local PAIO's.

PAIO offices also create strength reports that usually stay within the installation and they can be created daily, weekly, or monthly at the discretion of the installation commander. The strength reports often do not match the ASIP numbers because the MTOE/TDA authorizations, which are officially allocated slots for jobs, typically may not match what is currently present on the installation. Local PAIO cannot change their force structure, but they can move companies or squadrons to match the TDA (Ryman 2013). The PAIO does not track daily visitors to their installation. Strength reports could be an option to capture per-capita daily water consumption, but since it would still not capture actual visitor data, a fairly high degree of error could still apply. Team visits to installations discussed below identified other available data that could be combined to reduce some of this error.

Regardless, estimating the per-capita water metric accounting for the entire permanent and serviced population is a challenge. Personnel at ASIP follow AR5-18 in how they track personnel numbers, which does require a certain process, but does not require statistical analysis (Ryman 2013). For the purpose of creating a per-capita metric, data from ASIP is a readily available and verifiable resource that could be combined with surrounding population data tracked by DEERS to create the best estimate of the popu-

lation that uses the services in any one installation. The problem is to provide a statistical level of confidence to support these sources since neither ASIP data nor DEERS account for persons who visit the installation, use the facilities, and then leave every day.

The ISR details measures that are calculated from annual or quarterly metrics from reporting organizations. These metrics may include number of utility connections, or the number of unplanned water service disconnections. Depending on the service, they also may take DEERS' surrounding population data that is assigned by ASIP and use it to size the services available on the installation such as gyms and MWR facilities. The measures that require DEERS as a factor in sizing may provide an avenue to estimate the average use of the services on an installation, but not to estimate the average use of administrative or barrack type buildings. The ISR draws on multiple data sources, including DEERS, to determine the size of facilities. They base services sizing on Army standards. DEERS is one input used to size some base services, but it is not the only input and is it not used for every ISR measure to calculate every service size (Finks 2013). Thus, the service size does not directly correlate the actual numbers or real daily or quarterly use with surrounding populations that may visit an installation. This limits the confidence level in measuring per-capita water metric.

ASIP and DEERS data are only as accurate as the existing reporting systems, but those processes are still subject to human error. Regardless, broad assumptions on the per-capita water metric would have to be made by using the surrounding population data provided by DEERS combined with ASIP data to create a metric to fit the average installation. Despite these assumptions, these sources of data are the most reliable and standardized among all installations.

3.2.3 The Defense Manpower Data Center

The Defense Manpower Data Center (DMDC) tracks the number of personnel who live off installations down to the tenth of a mile radially by using mailing addresses. They use personnel data received directly from DEERS to track demographics throughout the Army and DOD. They are able to create a radial correlation of CAC card holders to an installation up to a given distance, but within that distance they are not able to track the installations that the CAC card holders may visit.

Data from DMDC could be useful in estimating possible CAC visitors at an installation, but only at remote installations. As such, DEERS data that presently account for CAC card holders could also be sufficient for remote installations. Coastal and metro area installations, where radial distances overlap, would allow a significant level of error in estimating “which serving population is visiting which installation.” The DMDC is capable of calculating these data for every installation quarterly, but such an effort would require a significant increase in man-hours quarterly (i.e., at least 1 hour for every installation) (Seggerman 2013).

3.2.4 Available Data at the Installation level

Team visits to Fort Buchanan, Tobyhanna Army Depot, and Aberdeen Proving Ground in January and February 2013 demonstrated that data to match or to be compared against the DEERS total served population surrounding an installation is not readily available. Two teams toured several unit offices from Housing, Medical, Schools, Security, Commissary, Master Planning, MWR offices, and the Department of Human Resources (DHR). Schools, Medical, and AAFES locations could provide some sense of daily use, but their current reporting process did not include reporting to the PAIO. They each had separate systems tracking their data and separate entities outside of IMCOM to report their daily counts.

Schools and housing had daily counts, but did not report these numbers to PAIO (Ortega 2013). The medical clinic and pharmacy give monthly reports to MEDCOM, but give nothing to PAIO (Colon 2013). Gyms also had daily counts, but the counts were not considered especially accurate. These numbers went into a system called RecTrack. The gym RecTrack numbers are not sent anywhere, but they are kept locally as are the customer numbers from the Post Exchange (PX) and the commissary. Restaurants, golf courses, and other service locations do not track customer use (Peterson and Welsh 2013). New IMCOM policy would have to be written and coordinated between headquarter commands for the medical, school, housing, and gym data to be provided to DPW who could then provide it to AEWRS.

Further policy and implementation procedures would have to be coordinated for additional counting at golf courses and other high use service facilities. The combination of all these data sets could give an idea of quarterly use on an installation. However the implementation of this policy

would likely be the biggest hurdle to overcome to create a reliable process and per-capita water metric.

3.2.4.1 Security Gate counting

Security gate guard policies do not consistently require counting cars or passengers coming onto the installations. Thus, it is difficult to know what size population actually visits any installation. Ideally daily car counts and personnel entering the installation could give us a good indicator on the surrounding population use of the installation. However, this is not being done. Daily car counts are easier said than done as many large installations such as Fort Hood would require an automatic system to be installed to capture the volume of traffic entering besides keeping track of the number of passengers. Thus, it is unlikely that counting cars and/or passengers at every gate would be an accurate method to capture visiting personnel. In addition, it would require significant investment in personnel time and possible equipment installation to capture the daily count.

3.2.4.2 Error in on-base housing data

One of the few daily trackers is housing data, but even in the housing occupancy numbers, family size is not always known. In addition, the numbers of personnel who live in the barracks, as opposed to the number who live off base, is not tracked, but can be easily estimated using ASIP data. The most direct way is to take the occupancy numbers of the base housing and the barracks and subtract from the total number of assigned personnel. This calculation is still prone to error in that base housing does not track whether the spouses of service members who live on base are also service members (Seggerman 2013). As of 2010, it was estimated that 5.1% of active duty Army personnel were married to another service member (DMDC 2010). Of this population, it is not clear which part of the 5% live on or off base with their spouse. Interviews with installation PAIO's indicate that, while ASIP data does not include housing data, it could be made available to the PAIO office for collection if required (Dudek 2012, Sanchez 2012).

3.2.5 Tracking Commuter flow

One way regional analysis is done is through tracking the commuter flow data provided by the US Census Bureau. Through their surveys, they are able to track commuting flow numbers that indicate residents who work in

one county, but live in another. Opposing tables also provide data correlating those who live in one county, but work in another. The combinations of both data sets indicate the flow pattern between counties or within a surrounding metropolitan area. For example, a county can be classified as a typical bedroom community if the commuting flow shows more residences are working outside the county rather than within. However, for the purpose of calculating per-capita water metrics at the installation level, this data is too “macro” in nature; it does not indicate the industry that is causing the commuters to flow in any one direction.

3.2.6 American Water Works Association (AWWA)

Known water conservation metrics developed by AWWA give guidance on how to clarify a per-capita water metric. This metric is typically based on a simple calculation: dividing the number of people served by the overall amount of water withdrawn. However, complications arise when the definitions for either factor in the calculation differ depending on the locations. In addition, the meaning and use of the term water metric, may change depending on the context of discussion (e.g., engineering, regulatory, or hydrologic). Other complications that can increase errors in the per-capita metric include the difficulties that municipalities and Army installations have in determining their overall populations served.

A study done by AWWA on seven cities throughout the United States with various climates, demand patterns, and account definitions performed regression analysis on account types to create comparisons between cities. Their method aimed to quantify an equivalence between account types and users in an attempt to eliminate errors associated with served populations. Despite this shift in accounting, the study ran into difficulties as service account types definitions differed depending on the location. For example, the Rio Rancho utility north of Albuquerque, NM defined multifamily accounts as only three- and four-plex apartments; anything larger was considered commercial. By contract, all of Tampa’s residential properties that are not single family homes are considered multifamily. The study attempted to compare consumption between residential homes and to capture equivalent consumption ratios with commercial, industrial, and agriculture uses (Dziegielewski and Kiefer 2010).

The study found that it was difficult to compare demand patterns based on climate and classification, and to create a meaningful metric that captures equivalent uses between cities, when the definitions of the primary categories differed (or overlapped) between locations. The final conclusions recommended long-term tracking within individual locations, but called for clearer definitions of terms before attempting to make comparisons between locations that account for climate factors.

Such studies can provide insight into the additional options available to Army installations in tracking water use. Data from nearby regional case studies may help Army installations check their calculations of per-capita metrics. However, most Army installations lack consistent, building level metering. This lack of metered use data would make it difficult to verify whether the installation's per-capita metric is reasonable or whether source data drawn from the surrounding population is reliable.

3.2.7 AWWA Research Foundation (AWWARF)

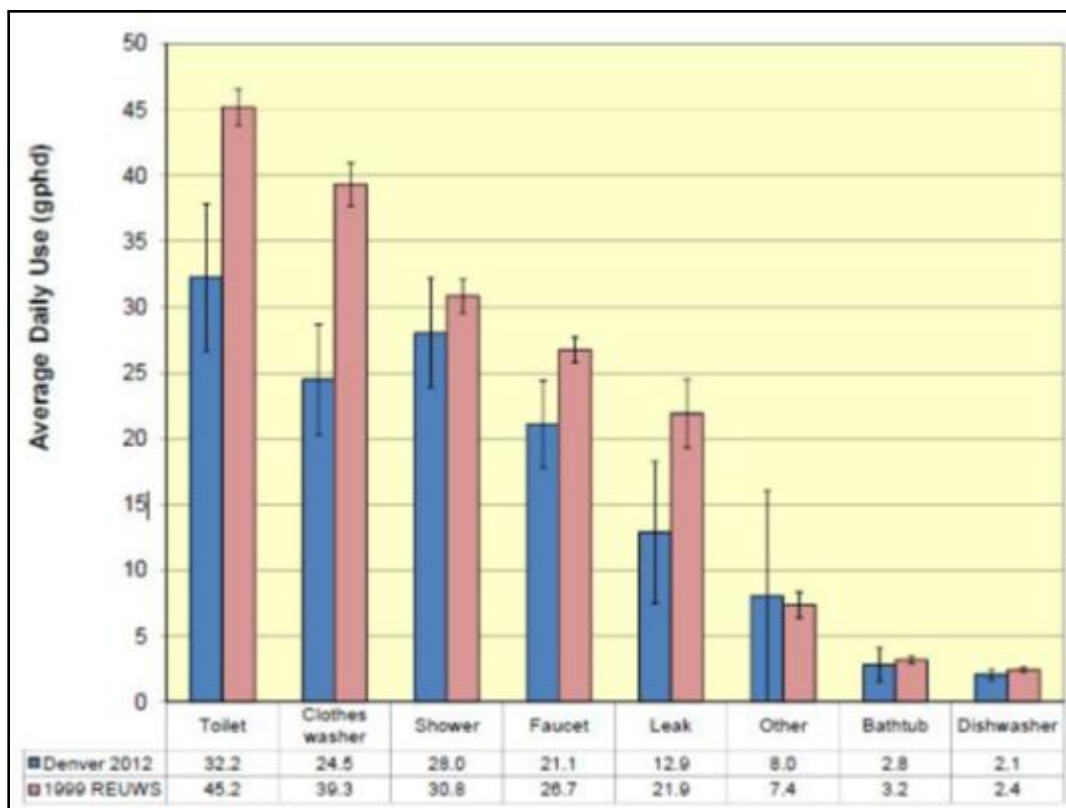
Research on per-capita water use attempted to account for daily demand based on human behavior, demographics, and duration of use. Oft-cited works include the 1999 and 2000 studies on water end-use sponsored by the AWWARF. These studies are often considered by utility managers as the most authoritative estimates for water demand at the fixture and user level. However, these studies may not be the most accurate reference for military installations. The AWWARF research focused on municipal type uses, leaving end-use gaps for barracks and military-specific industrial uses such as tactical vehicle washing and specialized military training like chemical decontamination. Moreover, these studies are now over a decade old. Since they were published, the average per-capita water use in the United States dropped even though the population and economy grew. This reduction may be due to increases in water use efficiency, and possibly to changes in patterns of use (Pacific Institute 2009).

The Water Research Foundation, formerly AWWARF, sponsored research into determining new water end-use patterns for residential locations. This study is in its third year of updating the 1999 residential end-use factors. Interim results, which used Denver as an early example, indicate that end-use (measured in gal/household/day) has fallen significantly (Figure 7). For example, at the fixture level faucet water use is down 21%, shower water use

is down 9%, and water demand for toilets is down 29%. These significant changes in Denver's water use suggest that fixture efficiency is affecting typical demand, and/or that use patterns may have changed. Thus, general estimates of water use probably also need to be updated. Updated numbers and frequency of uses per day are unavailable. The Water Research Foundation study will be completed in 2014 (Mayer and DeOreo 2013).

Plumbing fixture efficiency can vary widely throughout an installation and even within a building. Despite having years of experience managing facilities, most DPW energy and water managers do not track the type of water fixtures within installation buildings. Therefore, labor-intensive building level audits are necessary to capture fixture data to enable estimating water end-use. Water use assumptions are often based on estimated demographic information, building occupancy, hours of use, and some type of use factor, typically those developed through the 1999 AWWARF demand studies.

Figure 7. Example of end-use summary for Denver (interim results).



Water Research Foundation 2013

3.2.8 Discussion and recommendations

Broad assumptions are made quarterly using the surrounding population data provided by DEERS reconciled with on-base ASIP and housing data—to create a metric usable for remote installations, that is, those that are 80 miles or more from other military installations. A 95% level of confidence to support these data sources is difficult since neither ASIP nor DEERS account for persons who visit the installation, use the facilities, and then leave every day. At remote installations, this would provide an 80% solution for a per-capita metric as these data are updated quarterly. Unfortunately, a daily per-capita metric would not be accurate (or even possible to track at this time).

Unless actual building level water audits or metering is accomplished, further refinement of per-capita water use at the building level would interject further conjecture.

3.2.8.1 Recommendations

A combination of efforts will be required to capture a daily per-capita metric at a shorter frequency than possible by using existing quarterly data. Below are some suggestions as to how this might be accomplished.

To capture daily per-capita use for better than an 80% solution, an installation should:

- strategically install meters for barracks groups, housing, AAFES, MWR, irrigation, and other high use facilities and activities
- require all meters to send data to the Meter Data Management Systems (MDMS) at each installation
- request DPW energy and water managers with access to MDMS to reconcile population data using ASIP, DEERS, on-base housing, and high use buildings and input this data into AEWRS.

The following formulas may be used for reconciling.

Barracks Group “X” (Including DFAC’s):

$$\begin{aligned} &[(\text{Average \# of personnel in Barrack X for month Y (Avg Person/Month)}) \\ &\quad / (\text{Barrack “X” monthly demand (Gal/month)})] \\ &\quad / [\text{number of days in month Y (30 days/month)}] \\ &= \text{Gallons/person/ day} \end{aligned}$$

Administrative Group “A”:

Estimated Average Occupancy of all Group “A” buildings (Persons/month)*(1/3)*
 /(Group “A” monthly demand (Gal/month))
 /[number of days in month Y (30 days/month)]
 = Gallons/person/ day

If DPW personnel can make reasonable population estimates with ASIP and DEERS data, they can use the strategically placed water meters to disaggregate total water use to gain an 80% solution for daily per-capita water use, if not for the entire installation, then for the major users. If areas are irrigated separately from grouped buildings, then irrigation water demand should be divided between all building groups tracked.

3.2.9 Potential operational definition using quarterly data

Measure Number: 8-3.1.2

Owner: DASA(E&S)

Major Objective: Calculate quarterly per-capita water demand

Army Campaign Plan Objective: Achieve Energy Security and Sustainability Objectives (8.0)

Description: Daily estimate of water demand based on potential users on installation

Lag/Lead: Lag

Frequency: Quarterly

Unit Type: Percent

Preferred Trend: Down

Formula: Average daily water demand(Gal/day) divided by the sum of the average daily dependent visiting population (DEERS populations served subtracting ASIP data then multiplied by 1/6) plus normal nightly occupancy (housing data) plus normal daily visitors (ASIP data subtracting housing data then multiplied by 5/12).

Data Sources: Assigned military and civilian personnel population numbers are available from the ASIP system. Population-served numbers are available from the annual DEERS report. Water demand is available from AEWRS on a

* 1/3 multiplier is used for administrative buildings as it is assumed that these buildings are only occupied 8 hours out of the day on average.

quarterly basis or from the DPW on a monthly basis. Average daily numbers are available from the DPW housing office to include barracks, billeting, transient housing, and base housing. The 1/6 multiplier is based on assuming daily visitors are on base only 4 hours. The 5/12 multiplier is based on assuming a normal business day requires 10 hours on installation.

Data Quality: Variable

Data Collector: Energy and Water Manager

Baseline: None

Target: Fiscal Year 2015: xx%

Target by calendar quarter: 2015 1stQ xx%; 2ndQxx%; 3rdQxx%; 4thQxx%

Target Rationale: A per-capita measure offers an alternative measure of water use at an installation than using square footage. Large deployments, both outgoing and incoming, will spike water use when only square footage is used. In addition, some large water use activities are more closely associated with population than a building's footprint. Using quarterly data will lag significantly, but should show how deployments affect per-capita demand.

Strategies: Request that energy and water managers gather and calculate per-capita numbers (derived from ASIP, DEERS, and housing data) and report them as part of their ISR report and input into AEWRS, being sure to:

1. include water per capita metric in quarterly ISR reports
2. require input of installation-specific population data into AEWRS to perform per-capita water use calculations.

Cost: \$XM

Accuracy: TBD

Validity: Using gallons per person per day directly addresses potable water consumption.

Reliability: The population at an installation can vary by an unknown amount on an unknown frequency. The focus might be put on estimating the permanent population vs. the transitory population. It should be reliable for remote installations. For adjacent installations it will be difficult to determine if the population served data from DEERS is accurate.

Relevance: The measure draws on multiple data sources that may not be simple to gather and may not be timely.

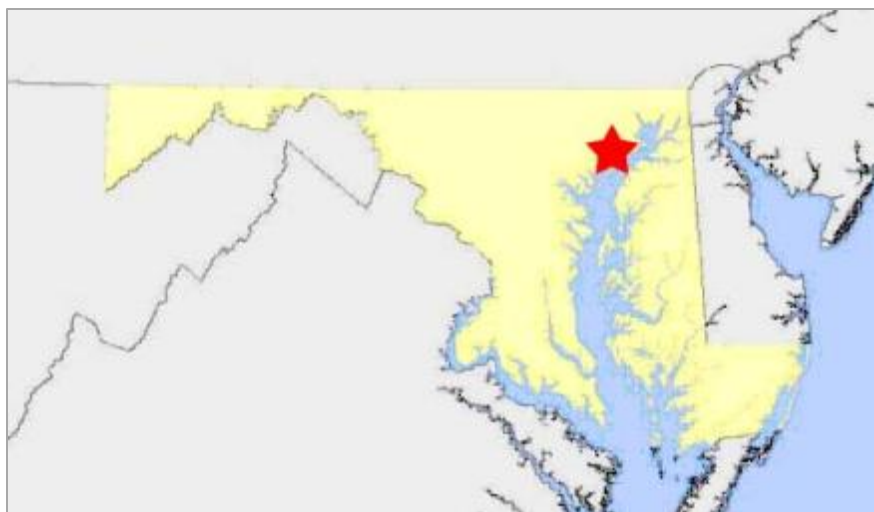
4 Aberdeen Proving Ground

Aberdeen Proving Ground (APG), established in 1917, is the US Army's oldest active "proving ground" (i.e., a place used to test items such as scientific equipment and theories). During World War II, APG housed up to 2,348 officers and 24,189 enlisted personnel. APG occupies over 72,500 acres in Harford County, MD, along the shores of Chesapeake Bay (Figure 8). The Bush River separates the installation into two general areas. The Susquehanna River and the Chesapeake Bay meet at its north and the Gunpowder River borders its south (Powers, APG 2012, p 2). APG currently supports 2,148 military family members and over 16,000 military retirees and retiree family members. In addition, 7,500 civilians, 5,000 military personnel, and 3,000 contractors and private business employees work at APG, MD (APG 2012). The 2005 Base Realignment and Closure (BRAC) expanded APG by 8,200 direct jobs to an installation population of nearly 22,000 active duty and civilian personnel.

4.1 Regional characterization

This section describes the natural and human systems that influence the development and outcomes of the regional water balance of APG.

Figure 8. Aberdeen Proving Ground, MD.



Source: Maryland Department of Planning (2013a).

4.1.1 Climate

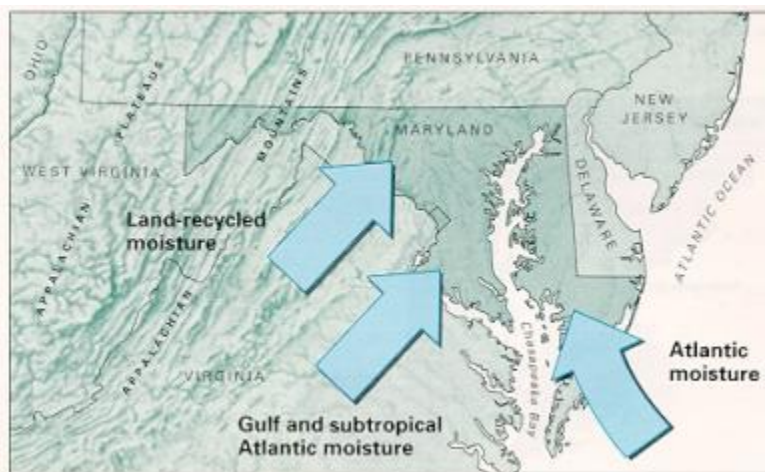
APG lies within Harford County, MD. Harford County receives an average of 45 in. of rain and 18 in. of snow every year. By comparison, US average precipitation is 37 in. of rain and 25 in. of snow (Maryland Department of Business and Economic Development 2012).

Three principal sources of moisture contribute to precipitation in Maryland (Figure 9). Summer and early autumn moisture originates from tropical air masses over the Atlantic Ocean. Winter moisture stems from tropical maritime air from the Gulf of Mexico and the Caribbean Sea. Moist ocean air typically mixes with water that has been recycled between land, vegetation, and air as the air moves inland. Moisture also stems from local and upwind land surfaces, and from lakes and reservoirs (James et al. 2012).

4.1.2 Water sources

The City of Aberdeen obtains publicly used water from 16 wells that are connected to a Quaternary aquifer. The APG water source is pumped from Deer Creek, a major stream in Harford County that originates in north-western Harford County and Baltimore County and that flows into the Susquehanna River just above Rock Run Mill in Susquehanna State Park. The Chapel Hill Water Treatment Plant processes an average of 1 million gpd, which includes the water that APG uses. When water from Deer Creek cannot meet demand, Harford County purchases water processed by the City of Havre de Grace (James et al. 2012).

Figure 9. Principal sources and patterns of delivery of moisture into Maryland.



Source: James et al. (2012).

4.1.2.1 *Deer Creek*

Deer Creek's source water protection area is about 164 square miles (105,216 acres) of mixed land (City of Aberdeen Department of Public Works 2012, 6). Deer Creek extends from Harford County, MD into York County, PA (Figure 10).

Harford County purchases water from the Town of Havre de Grace when the water flow at Deer Creek is too low or unavailable (Avila and AECOM 2011).

4.1.2.2 *Winters Run*

The drinking water for the Edgewood Area of APG is pumped from Winters Run and treated by the Van Bibber Water Treatment Plant (APG 2012).

Winters Run is a watershed that is part of the Bush River Basin and supplies water to the Town of Bel Air as well as other towns along its tributary primarily for agricultural purposes (Maryland American Water 2011, Maryland DNR 2000). Winters Run is located in Harford County, 1.2 miles northeast of Benson and 1.8 miles southwest of Bel Air. It is 10.5 miles upstream from the mouth and has a drainage area of 34.8 square miles (USGS 2012a).

Figure 10. Deer Creek and Winters Run.



4.1.2.3 Aquifers

Individual wells in Harford County generally receive their water from one of two geologic areas: the Piedmont, located west of Interstate Route 95, and the Coastal Plain, located east of Interstate 95 (Harford County Health Department Resource Protection Division 2009). Unconfined aquifers composed of fractures in bedrock capture drinkable water in the Piedmont from rain. Well yield ranges from 1 gpm to 40 gpd (Harford County Health Department Resource Protection Division 2009).

Water in the Coastal Plain is derived from saturated sands and gravels. This aquifer is typically confined by an impervious clay layer. The water production of the Coastal Plain averages 30 gpd, but more is not uncommon (Harford County Health Department Resource Protection Division 2009).

Three aquifers are located in APG: Quaternary terrace 2 (Qt2), Quaternary terrace 3 (Qt3), and Cretaceous. Recharge to the water table aquifer in the western portion of the Aberdeen Area of APG (APG-AA) is greater than the eastern portion. The Qt3 water table aquifer consists of a highly permeable sandy, gravelly medium approximately 40-60 ft thick. Harford County production wells draw significant amounts of water from the Qt3 aquifer. 11 City of Aberdeen Production (CAP) wells included in the Whitten et al. (1997) study were shown to be from the Qt3. The 11 CAP wells have produced between 1 and 1.5 mgd from 1986 through 1997. The Cretaceous formations in APG are typically poor water producers (Whitten et al. 1997).

The Qt2 aquifer has three units: A, B, and C. The Qt2 Unit A aquifer consists of sands and gravels located between the Qt2 Unit B aquitard and the finer grained Cretaceous sediments. Qt2 Unit A has very little aquifer data. APG-AA has several wells across Qt2 Unit B and A that can produce 400-500 gpm (Whitten et al. 1997).

4.1.3 Water suppliers

The Aberdeen Proving Ground is divided into two areas: Aberdeen Area (APG-AA) and Edgewood Area (APG-EA). Each area has its own water supply system. APG-EA is served by a water treatment plant in the Van Bibber area that has an allocation permit to withdraw a maximum of 4.5 mgd of water from Winters Run. The Winters Run stream has a zero safe yield as a water source, due to the required flow-by criteria that frequently

requires the plant to stop production due to low flows in the stream during late summer and early fall. In seven of the last eight summers, this plant was unable to withdraw water from Winters Run due to low stream flows.

Privatization of this Federal facility is pending. The water system for APG-AA has been privatized; the City of Aberdeen has taken over the system. APG-AA is served by the Chapel Hill Water Treatment Plant, which is supplied from Deer Creek. Deer Creek also has a zero safe yield during times of drought due to flow-by requirements that cannot be maintained during moderate drought conditions. A water availability study of the Deer Creek Watershed, recently conducted by the Susquehanna River Basin Commission, has revealed that, in times of drought, Deer Creek has insufficient water to become a major drinking water source without backup supplies. Therefore, the water allocation from this source is tied to adequate reliable backup supplies. The permitted withdrawal rate from Deer Creek is 1.8 mgd. Backup supplies are provided by the City of Aberdeen wells (0.3 mgd) and Harford County (1.5 mgd).

APG North obtains its drinking water from the Chapel Hill Water Treatment Plant through a contract with the City of Aberdeen, whereas APG South obtains it through the Van Bibber Water Treatment Plant, which is owned and operated by the garrison (APG News 2012). APG drew its own groundwater in the early 1900s from an on-site water treatment plant (hereinafter referred to as The Building). The facility once drew between 2 and 3 million gpd of water from this source, but it is currently abandoned (Kuchar 2013). Plans to refurbish The Building and its water-drawing capabilities are underway (Kuchar 2013).

APG-EA has on-site groundwater supply networks that are now abandoned. In 1941-1942, the Canal Creek Groundwater Treatment Plant was constructed to treat water from the groundwater supply. The treatment plant consisted of cascade aerators and four rapid sand filters with a total capacity of 2 mgd. The wells were maintained and used as production and stand-by wells until 1984, when sampling and analysis of the water by the State of Maryland determined that the groundwater pumped by the wells was contaminated with volatile chlorinated organic compounds. In 2000, the plant was re-purposed to pump, contain, and treat the contaminated groundwater. Plans are underway to beneficially reuse the treated

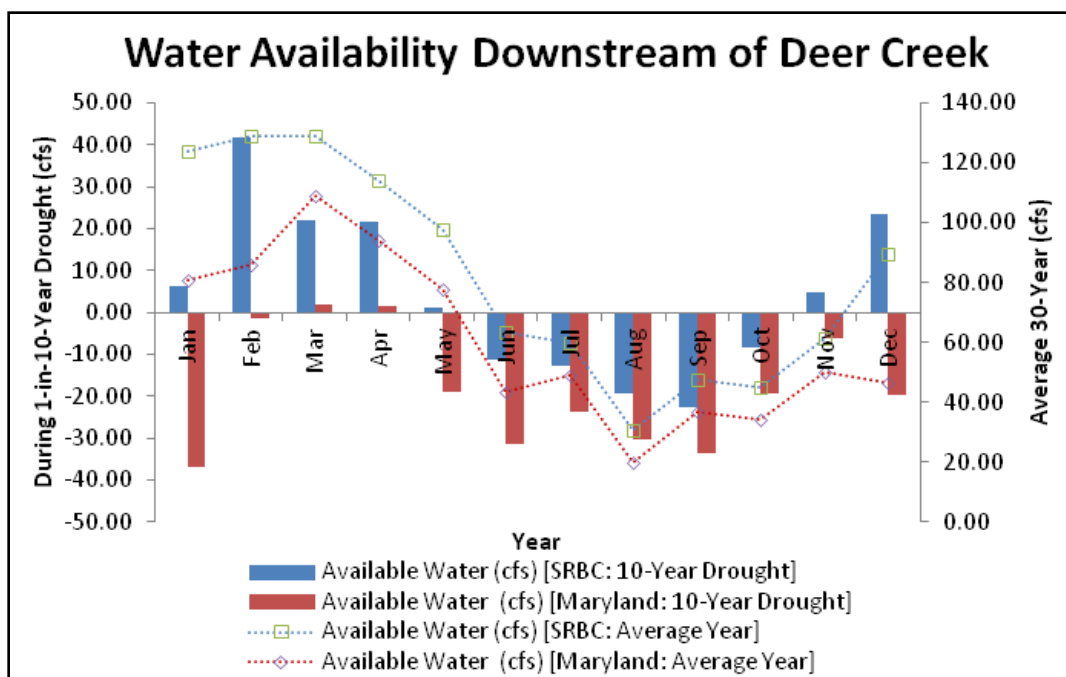
groundwater as boiler make-up water in Bldg. E5126, the main boiler plant in EA (Wrobel 2013a).

4.1.4 Water rights and issues

The Susquehanna River Basin Commission (SRBC) and Maryland Department of the Environment (MDE) have separate policies considering the proper passby rate, i.e., the amount of water deemed necessary to preserve the natural state of the Deer Creek tributary (Figure 11). Neither MDE nor SRBC will approve water withdrawal if stream flow conditions fall below the allocated passby flow allocation at the Darlington gage site. SRBC's passby rate is 46 cubic feet per second (CFS) from July through February and 69 CFS from March through June; MDE's passby rate is 57 CFS from July through November and 89 CFS from December through June.

Other water withdrawals upstream of the Darlington gage include permitted use and non-permitted use rates. MDE and SRBC share the flow rate values during average and drought seasons: 3.09 CFS and 4.33 CFS, respectively. APG is permitted to withdraw 4.62 CFS from the Deer Creek River contingent with the remaining availability of stream flow.

Figure 11. Available downstream water during average year and 1-in-10-year drought.



Source: SRBC (2008).

Harford County agreed to provide potable water for purchase by the City of Aberdeen in the Bulk Water Agreement (City of Aberdeen 2011). This agreement was amended in October 2009 to provide up to 0.9 million gallons per day (mgd) to the City of Aberdeen to meet commercial and industrial development within the corporate limits of the City of Aberdeen resulting from BRAC. Additional sources may be purchased from the County according to the Bulk Water Agreement between Baltimore, Harford County, and the City of Aberdeen, depending on whether the county has the capacity to sell (City of Aberdeen 2011).

The Maryland American Water Company provides service to the Town of Bel Air and to county areas adjoining Bel Air, serving approximately 13,800 residents. Its water plant draws water from Winters Run (up to 1.4 mgd) and two wells (up to 0.355 mgd). In addition, Maryland American may receive up to 500,000 gpd through a contract purchase agreement with the county. Maryland American average day demand was 1.6 mgd and its maximum day demand was 1.9 mgd. The water supply withdrawals from Winters Run are limited during times of drought and during late summer and early fall when rainfall is not plentiful due to minimum stream flow-by requirements (Harford County Maryland 2009, p 37).

American Water customers depend on the water of Winters Run. The population growth of American Water customers is based on the percentage of American Water customers against total population growth for census tracts along Winters Run. Furthermore, the volume of water consumed by those customers is based on the historical maximum daily demand of 1.9 mgd in 2000. The availability of water is calculated by subtracting the estimated volume needed by American Water customers from the average mgd withdrawn (2.255 mgd) during average flows (Figure 12).

4.1.5 Land use

In 2002, a land use study found that the Deer Creek Watershed of Harford County was composed of 27,078 acres or 31% of forest and brush, 46,128 acres or 54% of agriculture, 97 acres or less than 1% of barren land, and 12,635 acres or 15% of developed land (Figure 13). Development between 2002 and 2010 has been negligible although a few instances of expansion around previously developed areas are noticeable north of the Edgewood Area (Figure 14) (MDE 2006).

Figure 12. Winter's Run water availability and population growth forecast of American Water customers.

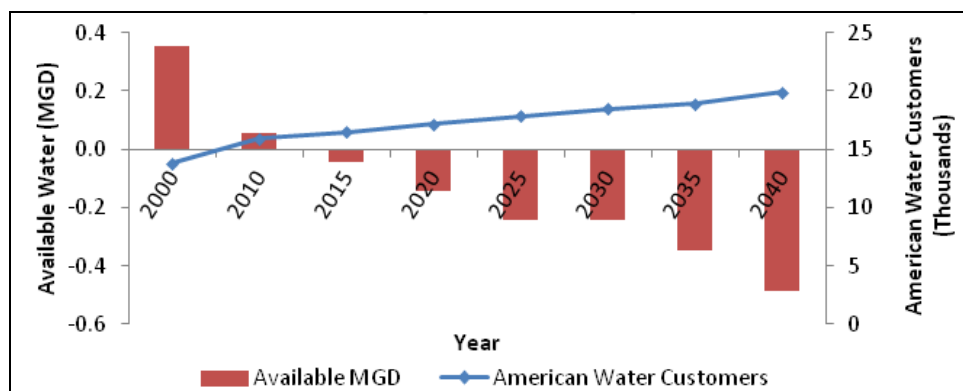
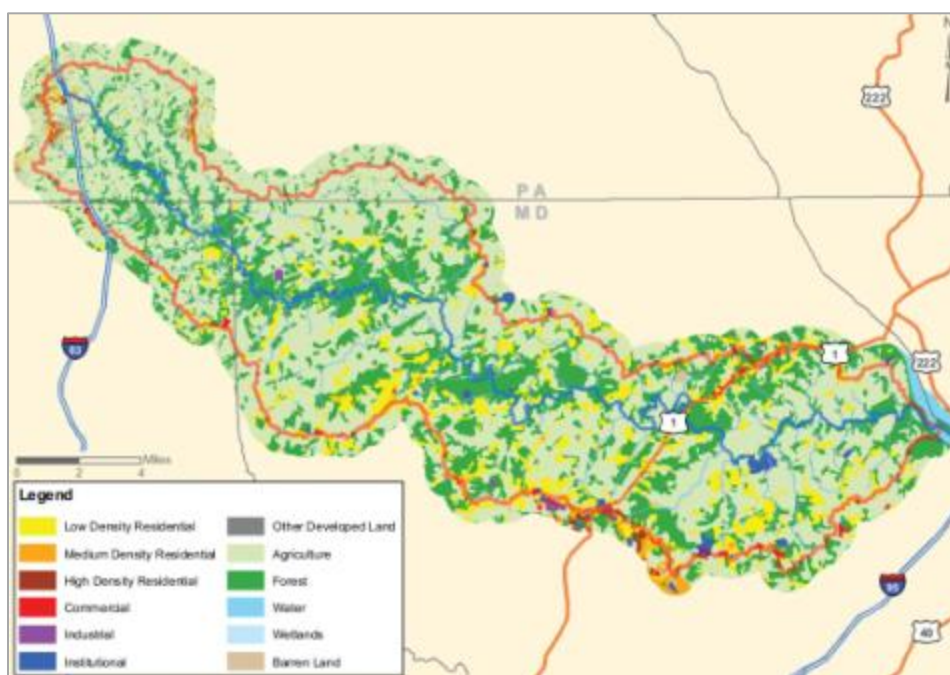


Figure 13. Land Use around Deer Creek Watershed in 2002.

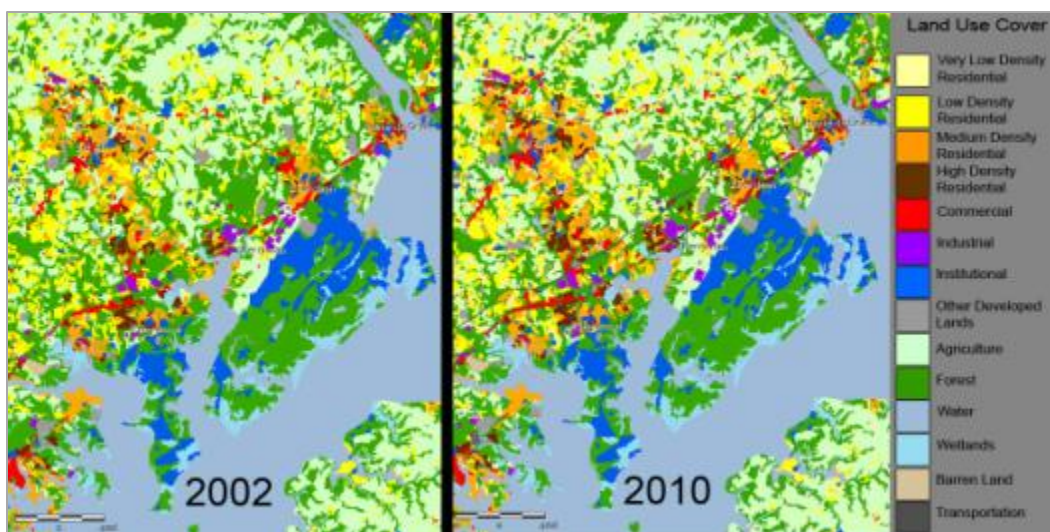


Source: SRBC (2008).

4.1.6 Demographic trends

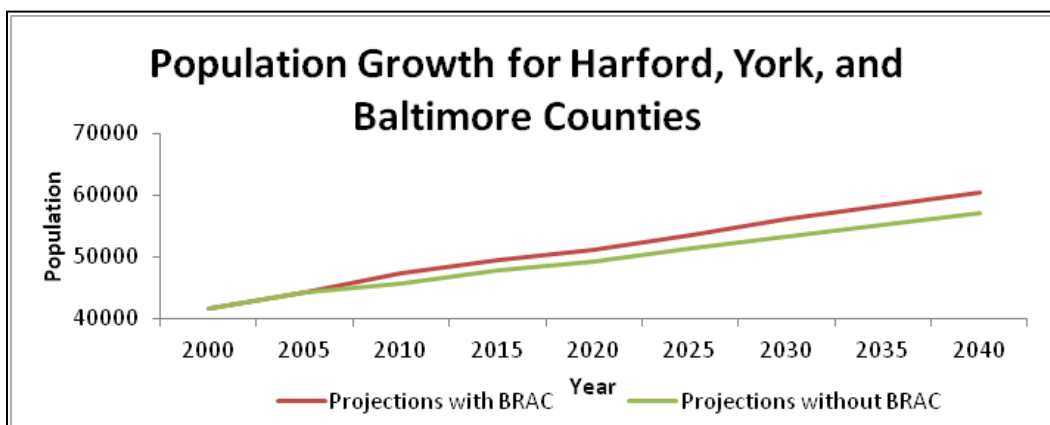
Since 2005, the BRAC transfer at APG has added six organizations to the installations, 8200 direct jobs, and 2.8 million sq ft of new and renovated building space (Gallo 2012). In 2012, those jobs included over 6300 personnel (civilian DOD, embedded contractors, and military). By 2017, direct, indirect, and induced job growth created by BRAC is estimated to exceed 30,000 (CSSC 2012, OEA 2012). Figure 15 shows population growth projections, with and without BRAC, for Harford, York, and Baltimore Counties.

Figure 14. Land Use Comparison for 2002 and 2010.



Source: Maryland Department of Planning (2013a).

Figure 15. Population growth projection for Harford, York, and Baltimore Counties.



Source: SRBC (2008).

While the Van Bibber Water Treatment Plant has frequent difficulties in obtaining water, a contract between the City of Aberdeen and Chapel Hill allows APG to maintain water consumption rates through water purchase agreements with the county and neighboring towns. For example, 200 kgal of water were purchased in 2012. Interviews in January of 2013 revealed that, although the water remains drinkable, the taste quality of water drops noticeably when water is drawn from the Susquehanna River (Wrobel 2013b).

4.2 Projecting water supply and demand trends in the APG regional model

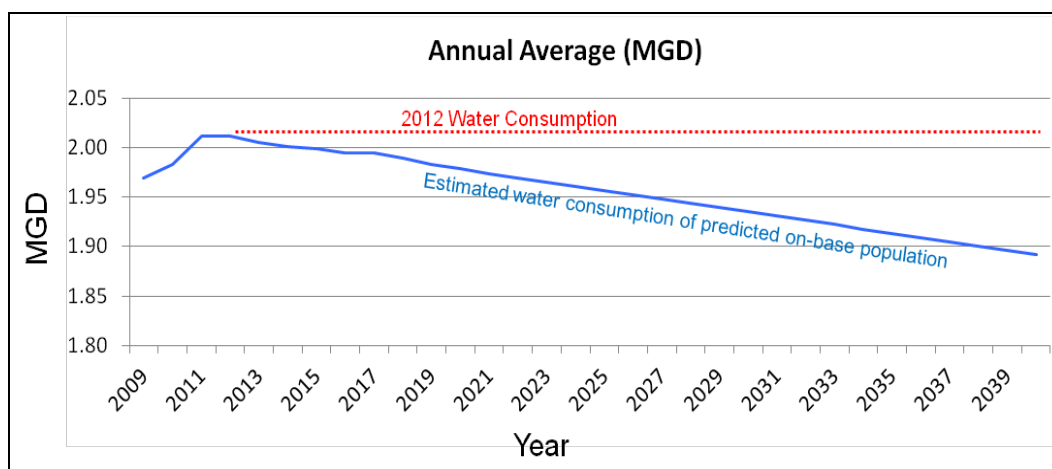
The objective of this section is to project water availability and consumption 30 years into the future for APG within the region of this study. Various scenarios were produced to review potential water scarcity issues to account for future uncertainty.

4.2.1 Scenario 1: Status Quo

Scenario 1 is the Status Quo scenario. The status quo scenario supposes that no additional measures beyond currently running policies are established or implemented. Historical population data from 2009 to 2011 (PNNL 2013a) and ASIP projections from 2012 to 2018 (ASIP 2012) were combined to calculate populations up to 2040 and to forecast the respective on-base water consumption trend (Figure 16).

Possible BRAC development in 2013 and 2015 was ignored. The decline in on-base population is attributed to a decreasing number of personnel in various contractor facilities (ASIP 2012). Other assumptions were also made to simplify this scenario including a continual supply of water from the City of Aberdeen to APG through the City's agreements with Harford County and neighboring towns during a drought. This current contract between APG and Aberdeen depends on much more complex and expansive contracts beyond the installation's control including agreements that extend beyond Harford County into Baltimore County and even into Pennsylvania.

Figure 16. Forecast on-base water consumption trend.



Scenario 2: Water dependence is isolated to Deer Creek and Winters Run

Scenario 2 disregards the agreements that the City of Aberdeen has with neighboring counties and cities. This scenario looks at how the installation would fare if it and the region had to solely depend on Deer Creek and Winters Run Watersheds for their water supply.

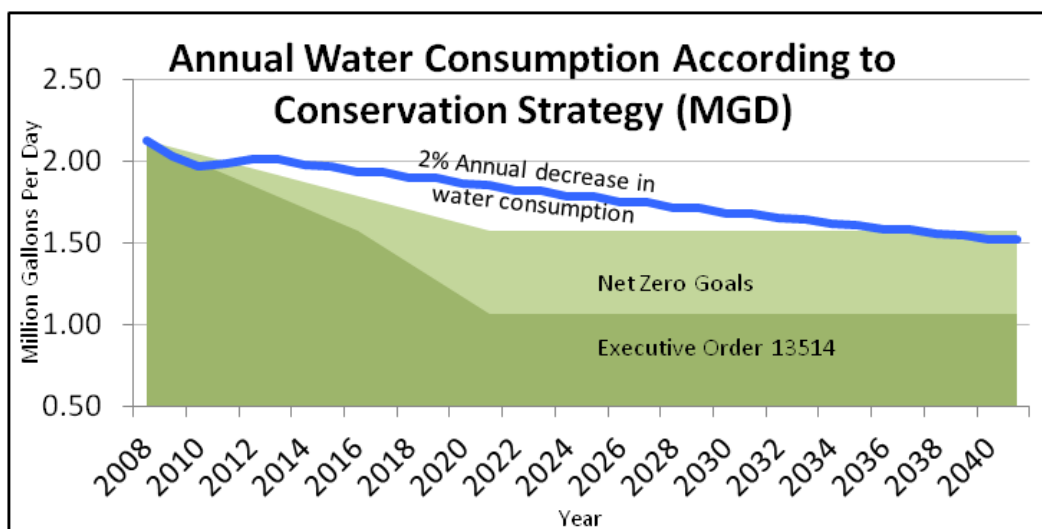
The greatest challenges in this scenario for water supply in and adjacent to the Deer Creek Watershed are population growth and urbanization, including those stemming from the BRAC plan for APG. Additional growth would put increased strain on a watershed that is already stressed beyond capacity during moderate drought. Under existing conditions, water demand exceeds available flow during some summer months in moderate drought years (SRBC 2008). The same challenges apply to APG-EA. The current population growth along Winters Run will reach a water consumption rate that goes beyond supply capacity in 2015 (Figure 17).

In this scenario where the region depends solely on local watersheds, an increase in the population growth rate or a climate-change-induced increase in the frequency of droughts would put the region in a highly vulnerable situation. Even the current situation indicates that the installation relies on a region that is overly dependent on resources beyond its boundaries.

4.2.2 Scenario 3: On-Site Water Conservation

Scenario 3 displays how an additional 2% annual decrease in water consumption compares to EO 13514 and the Army's Net Zero Water goals. EO 13514 mandates the reduction in annual potable water consumption by 2% until 2020 using 2007 as the base year. The Army's Net Zero goal also uses 2007 as the base year, but has a more aggressive 26% reduction goal by FY15 and a 50% reduction goal by FY20. Decreasing water consumption by 2% each year will yield results that fall short of EO 13514 and Army Net Zero Water goals.

Figure 17. Scenario 3: On-site water conservation.



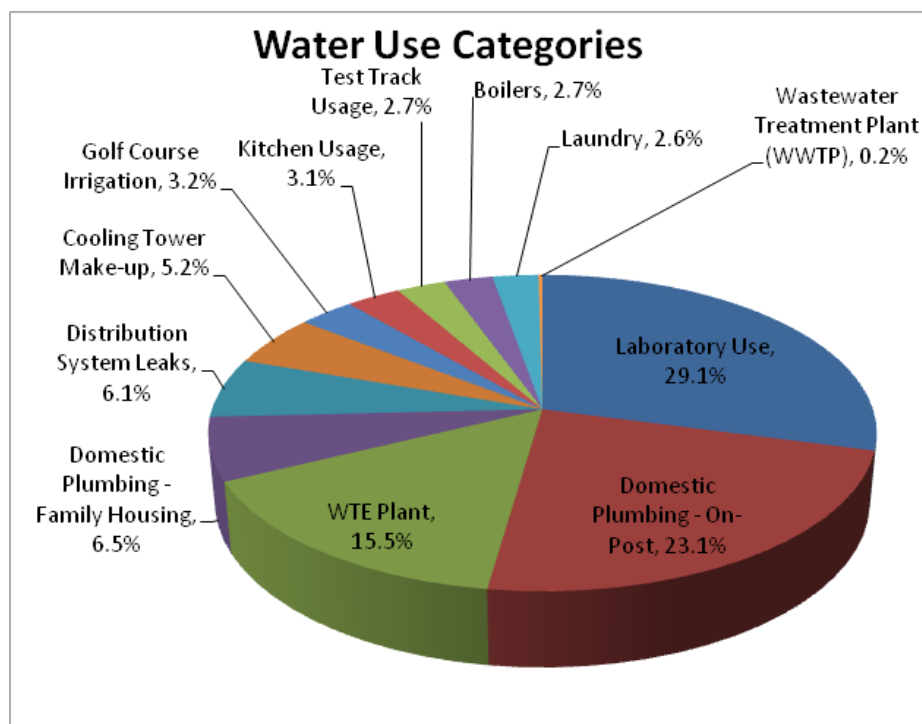
APG's top three categories of water consumption are laboratory use at 29.1%, domestic plumbing (on post) at 23.1%, and the waste-to-energy plant at 15.5% (Figure 18, PNNL 2013a). Targeting categories to reduce water consumption is typically the next step, but decades-old contracts that specify flat water use fees and the requirements of classified research that prevent water use information from being divulged are hurdles that may prevent moving forward quickly.

Scenario 3, like Scenario 1, depends on complex water agreements between the City of Aberdeen and other cities, counties, and states. Focusing on water conservation methods at the installation may help APG do its part in reducing regional water consumption and achieving the Net Zero Water goals, but it still leaves the installation vulnerable to climate change and water delivery agreements outside of its control.

4.2.3 Scenario 4: On-Site Well Usage

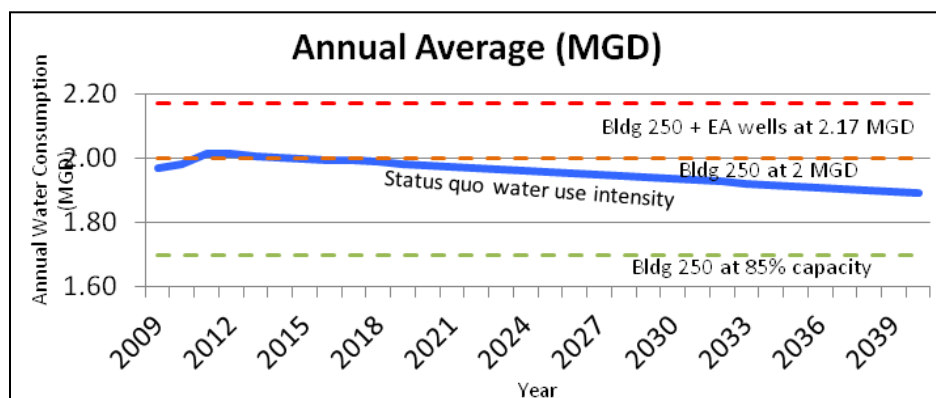
Scenario 4 examines the use of wells located on the installation. Bldg. 250 was an on-site water treatment plant in the early 1900s that tapped groundwater resources. It is currently abandoned, but there are plans to refurbish it. The Building offered approximately two to three mgd of groundwater when it was operational (Figure 19) (Kuchar 2013).

Figure 18. Water use categories of APG.



Source: PNNL (2013).

Figure 19. Groundwater versus status quo water use intensity (mgd).



Much of the groundwater in APG-EA is either contaminated or lost due to contamination that renders the water undrinkable and unusable (Agency for Toxic Substances and Disease Registry [ATSDR] 2008). Still, there are potential uncontaminated confined aquifers in APG-EA that could be developed as a resource as The Building is being proposed (Wrobel 2013). In addition, previously contaminated groundwater may be treatable for nonpotable use. The Canal Creek Treatment Plant would offer 150-170,000 gpd of nonpotable water that could be used in boiler plants if its water sources can be effectively treated (Kuchar 2012).

The Building would have to draw at the maximum rate to meet expected water demands in the future. The Building would not be able to supply enough water at the current usage rate nor at a safer 85% production level. However, APG could potentially meet full demand if both The Building and Canal Creek Treatment Plant were put to use (Figure 19).

4.3 Water sustainability assessment for the APG region

The water agreements between the City of Aberdeen with Havre de Grace, Harford County, Baltimore County, and other entities are extremely complex and will only increase in complexity in the future. There are multiple pipelines in place to make up for water supply shortages in the region including an 8-in. pipe Harford County has connected to the Chesapeake Bay. The dependence on neighboring cities, counties, and states is a vulnerability to the City of Aberdeen and APG. BRAC-induced regional population growth and climate change will put even greater stress on the installation's position. APG must put greater emphasis on becoming self-reliant when it comes to water resources. To do that, there are two major adjustments that need to be made: (1) switch to groundwater located at the installation and (2) increase water conservation efforts.

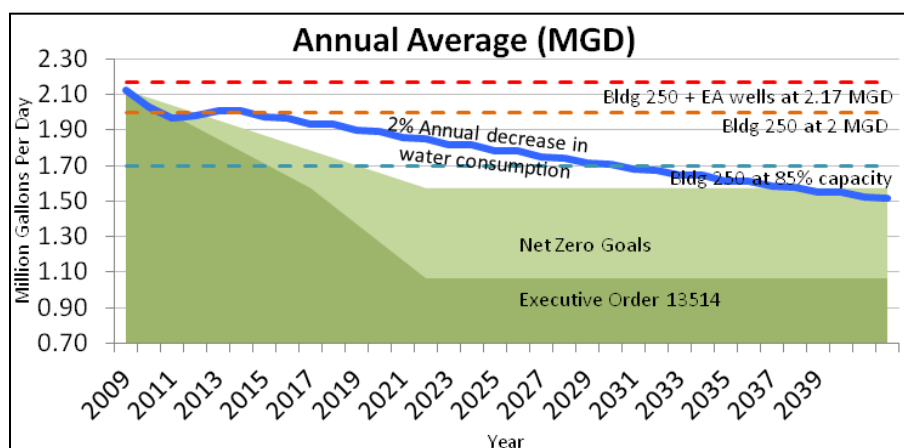
The use of The Building in the early 1900s implies that groundwater is already available at APG-AA. While water at the Edgewood Area is too contaminated to be usable, the estimated 2 to 3 mgd that The Building can supply could provide APG with a significant milestone towards the installation's Net Zero Water goals. The Building may need to be fully or partially privatized in the future to help the Army minimize the cost of refurbishment and maintenance.

A look at the existing privatization contract for Chapel Hill with the City of Aberdeen is needed if the Army seeks to enter into a favorable partnership. Feedback from APG personnel indicates that the existing privatization contract for Chapel Hill with the City of Aberdeen is an unbalanced arrangement. The issue of greatest concern with the current contract is that it does not avoid the high cost of maintenance for the Army; it only creates a pass-through to the City of Aberdeen for the capital costs (Rust 2013). Water agreements between APG and the City of Aberdeen are likely unavoidable because of the need for the installation to have backup options. Special focus on any contracts between the two will improve future benefits for APG.

The water use category that offers the greatest reduction potential for the installation is laboratory use, but it is also riddled with obstacles. Many of the APG tenants do not track or provide their water use data. Reasons include the classified nature of many research activities and a flat water use fee. Overcoming this hurdle may require major recalibration of upcoming contracts as well as those made decades ago.

APG's path to sustainability requires a combination of several policies and measures (Figure 20), as well as steps to simplify the installation's relationships with water supply sources and to more clearly break down how water is being used on the installation. Contracts that go back decades, installation-tenant relationships, and the cost of maintaining a water treatment plants are a few of many challenges that will be met to sustainability. Those hurdles, although difficult, should prove to be easier than having to maneuver among agreements between the cities, counties, and states beyond APG.

Figure 20. Scenarios combined.



5 Fort Buchanan

US Army Garrison Fort Buchanan, PR, also known as the “Sentinel of the Caribbean,” was established in 1923 (Heard 2012). Fort Buchanan grew to 4,500 acres in the 1940s, but gradually reduced its size. Today, the installation consists of 746.16 acres and serves a population of approximately 130,000 veterans, retirees, civilians, military personnel and their dependents in Puerto Rico, Virgin Islands, and Latin America (US Army Garrison [USAG] Fort Buchanan 2012). Fort Buchanan serves the Army, Navy, Marine, Air Force, and Coast Guard units, as well as other Federal agencies. The installation’s location provides fast, strategic support to missions in the Caribbean, Central America, and South America.

5.1 Regional characterization of Fort Buchanan

5.1.1 Brief

This section describes the natural and human systems that influence the development and outcomes of the regional water balance of Fort Buchanan.

5.1.2 Climate

Puerto Rico’s climate is tropical with moderate temperatures averaging 80 °F in the lower elevations and 70 °F in the upper elevations throughout the year. The winter months of December through March are dry throughout most of the island. The rainy season occurs from April to November, but not all parts of the island are affected equally during this time period. For example, rainfall in April is focused in the Cordillera Central, whereas the southern coast becomes arid. In June and July, the middle third of the island dries out, only to receive heavy rainfall in September and October. During the beginning of summer, rainfall is concentrated on the western and eastern parts of Puerto Rico; and October is characteristically wet for the entire island (Carter and Elsner 1997).

5.1.3 Topography and geology

Puerto Rico has a diverse environment including rain forest, deserts, beaches, caves, oceans, and rivers. The island is broken down into three

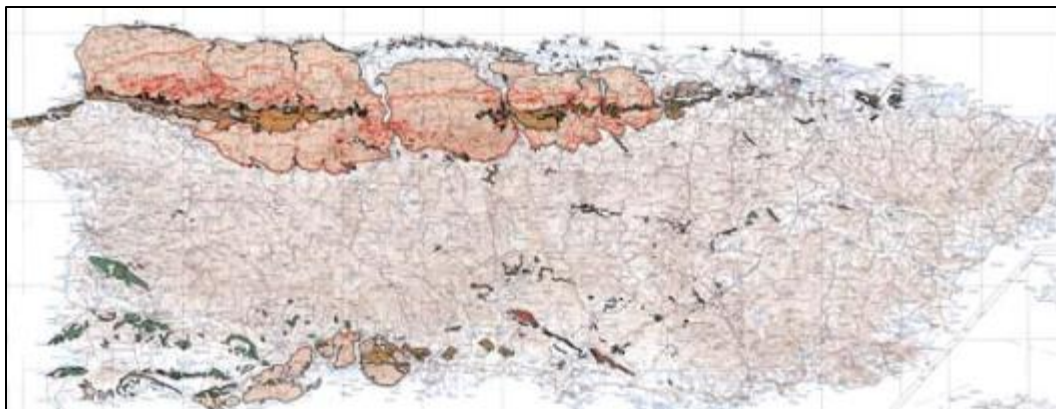
main physiographic regions: the mountainous interior that makes up 60% of the island, the coastal lowlands, and the karst area (Rivera 2013).

The island is comprised of about 60% mountainous territory (Figure 21). The karst area extends from Aguadilla, in the west, to Loíza, just east of San Juan. The area is characterized by a mix of limestone or volcanic rock that has been worn down by water and now features sinkholes, caves, and underground drainage systems.

5.1.4 Location

Fort Buchanan lies in the San Juan Metropolitan Area straddled by the municipalities of Guaynabo and Bayamón and near the borders of Cataño and San Juan (Figure 22). The San Juan Metropolitan Area is composed of 41 different municipalities. Within the metropolitan area, the Puerto Rico Aqueduct and Sewer Authority (PRASA)* provides water and sewer service to 12 municipalities including Bayamón, Caguas, Canóvanas, Carolina, Cataño, Guaynabo, Loíza, Río Grande, San Juan, Toa Alta, Toa Baja, and Trujillo Alto. Those 12 municipalities define PRASA's geographic service area. These 12 municipalities define the populated study region.

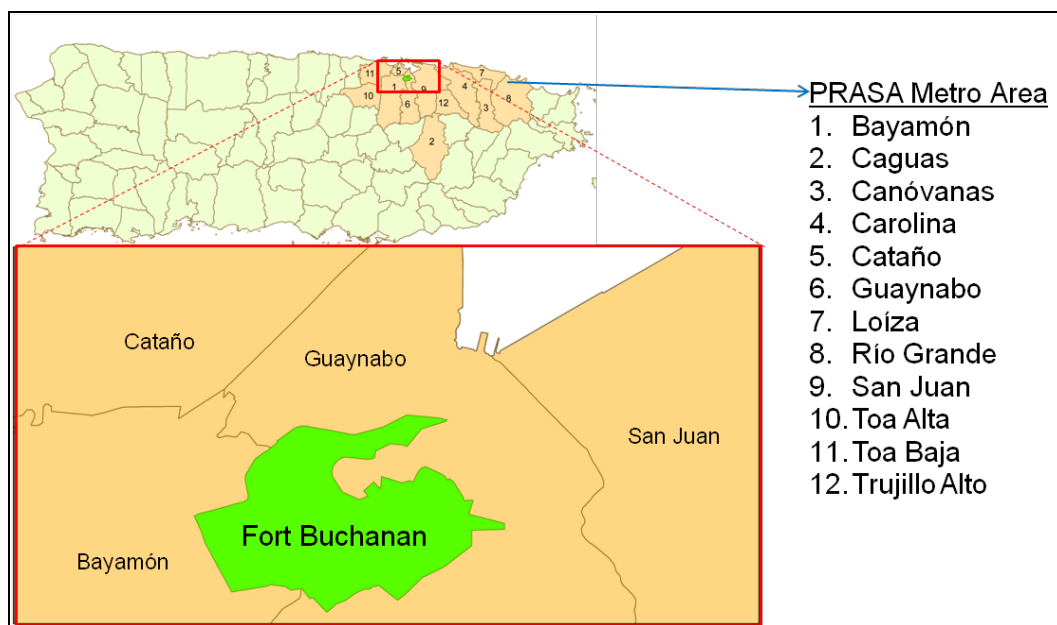
Figure 21. Karst map of Puerto Rico.



Source: USGS (2010).

* PRASA is known as *Autoridad de Acueductos y Alcantarillados (AAA)* in Spanish.

Figure 22. PRASA metro area.



Source: USGS (2012b).

5.1.5 Water supplier and water rights

PRASA supplies potable water to over 97% of residents in Puerto Rico (Angulo 2011, p 9) and serves approximately 55% of the population with their wastewater system. PRASA is a Puerto Rico government-owned corporation responsible for water quality, water management, and water supply in Puerto Rico (Presupuesto 1945).

PRASA maintains the infrastructure for public water distribution across Puerto Rico. As a result, many of the lines are connected. PRASA has been known to transfer water from one municipality to another during water shortages. PRASA controls how potable water is distributed and can thus choose to draw from one water source to maintain minimal flow rates in another.

5.1.6 Water sources

Fort Buchanan has three primary water sources: Lago Loíza, Lago La Plata, and the Superaqueduct that draws water from the Río Grande de Arecibo (Figure 23). This report focuses on these three water sources as the study area's main supply resources.

Figure 23. Water supplies for PRASA metro region.



Figure 24. Looking upstream to Carraizo Dam (Lago Loíza) under drought conditions.



Source: Matthew Larsen, USGS.

5.1.6.1 Lake Loíza

Lago Loíza is located in the municipality of Trujillo Alto. The lake is impounded by Carraizo Dam (Figures 23 and 24), which PRASA built in 1953. Lago Loíza has a drainage area of approximately 206 square miles. The reservoir originally could store 21,735 acre-ft, but sedimentation has caused a significant loss in storage capacity. The reservoir was first built to

generate 3 MW of electricity, but it is now exclusively used as a public water supply source (USGS 2008e).

The Sergio Cuevas Water Treatment Plant (SCWTP)* in Trujillo Alto treats the reservoir water. In 1994, SCWTP produced 89 mgd of potable water for over 750,000 people in municipalities including San Juan, Trujillo Alto, Caguas, Gurabo, and portions of San Lorenzo, Canóvanas, Loíza, and Río Grande (USGS 2008a-e).

When water supplies are low due to drought or other unforeseen circumstances, water may also come from Guaynabo and Bayamón (Negrón 2012). Loíza Reservoir supplies about 100 MGD of water to SCWTP to serve the San Juan Metropolitan Zone and parts of Trujillo Alto and Carolina (González 2009).

5.1.6.2 *Lago La Plata*

PRASA constructed the reservoir in 1974 in Toa Alta. The reservoir serves as a public water supply source for the people living primarily in Bayamón, Naranjito, and Toa Alta. This reservoir has a drainage area of 181 square miles. Lago La Plata (Figure 25) originally had a 35,598 acre-ft water storage capacity, but sediment infilling reduced it to 28,747 acre-ft. The Enrique Ortega Filtration Plant uses the water of this reservoir to produce approximately 42 mgd for about 350,000 people (USGS 2008d).

Figure 25. Upstream Lago La Plata Reservoir.



Photo by Matthew Larsen, USGS

* SCWTP is also known as Planta de Tratamiento de Aguas Sergio Cuevas Bustamante.

5.1.6.3 Superaqueduct

The Superaqueduct system consists of a 72-in. diameter high pressure pipeline (Figure 26), a 300-million gallon (1,136 million liter) reservoir, two 10-million gallon (38 million liter) storage tanks, and a water filtration plant in Arecibo that produces approximately 100 mgd (USGS 2008a).

Figure 26. Seventy-two-in. pipe.



Photo by Inter News Service.

The Superaqueduct system captures water from Caonillas and Dos Bocas reservoirs and transports it eastward along the northern coast to the San Juan area. The San Juan Metropolitan Area receives 65 of the 100 mgd of water distributed through the Superaqueduct (Inter News Service 2011).

5.1.6.4 Lago Caonillas

Lago Caonillas was constructed in 1948 in Utuado (Figure 27). The reservoir was built to generate hydroelectricity for the people living in the vicinity. The reservoir has a drainage area of 50.4 square miles. The reservoir's original water storage capacity of 45,124 acre-ft decreased to 34,268 acre-ft by the year 2000 due to sediment infilling (USGS 2008a).

Figure 27. USGS crew preparing for a bathymetric survey at Lago Caonillas.



Photo by Ramon Carrasquillo, USGS.

5.1.6.5 *Lago Dos Bocas*

Lago Dos Bocas (Figure 28) was constructed in 1942 in the Utuado. The reservoir was built to generate hydroelectricity. The reservoir has a drainage area of 170.0 square miles. The reservoir's original water storage capacity of 30,401 acre-ft decreased to 14,625 acre-ft by the year 1999 due to sediment infilling (USGS 2008c).

Figure 28. Lago Dos Bocas.



Photo by Senén Guzmán, USGS.

5.1.6.6 *Other water sources not accounted for in this study*

5.1.6.6.1 Lago Carite

The reservoir provides the Guayama area with potable water and provides the southeastern coastal plains of Puerto Rico with irrigation water through the east and west Guamani canals. Lago Carite also supplies the town of Cayey with water by means of a water intake about 300 m upstream from the dam at the right bank (Soler-Lopez 2001).

5.1.6.6.2 Lago de Cidra

The Lago de Cidra Reservoir (Figure 29) was constructed in 1946 in Cidra. It serves as a public water supply source for Guaynabo, Aguas Buenas, Cidra, and Comerío. The reservoir has a drainage area of approximately 8.6 sq mi. It originally had 5,302 acre-ft of storage capacity, but sediment infilling has reduced the capacity to 4,670 acre-ft. The Guaynabo Filtration Plant produces about 20 mgd to serve approximately 160,000 people (USGS 2008b).

Figure 29. Spillway at Lago de Cidra Reservoir.



Photo by José Agis, USGS.

5.1.6.7 Rainwater harvesting

Fort Buchanan's location offers between 65 and 70 in. of precipitation each year, ranking it higher than the top 10 wettest cities in the US mainland (Thompson 2007). Nine buildings were selected as part of a rainwater harvesting project to reduce the purchase of potable water from PRASA: (1) Fitness Center, (2) Post eXchange, (3) Community Club, (4) PXtra, (5) Bowling Center, (6) Hi-School Cafeteria, (7) Hi-School Gymnasium, (8) Middle School Cafeteria, and (9) Middle School Gymnasium (Johnson Controls 2011). It would be helpful to know how much water in each building originated from PRASA before and after rainwater harvesting, but the buildings do not have meters. The nine buildings can capture approximately 1.9 million cu ft or 14 million gallons of water annually from precipitation (estimated to be 68.97 in.) before considering evapotranspiration losses (National Weather Service 2013).

5.1.7 Demographic trends

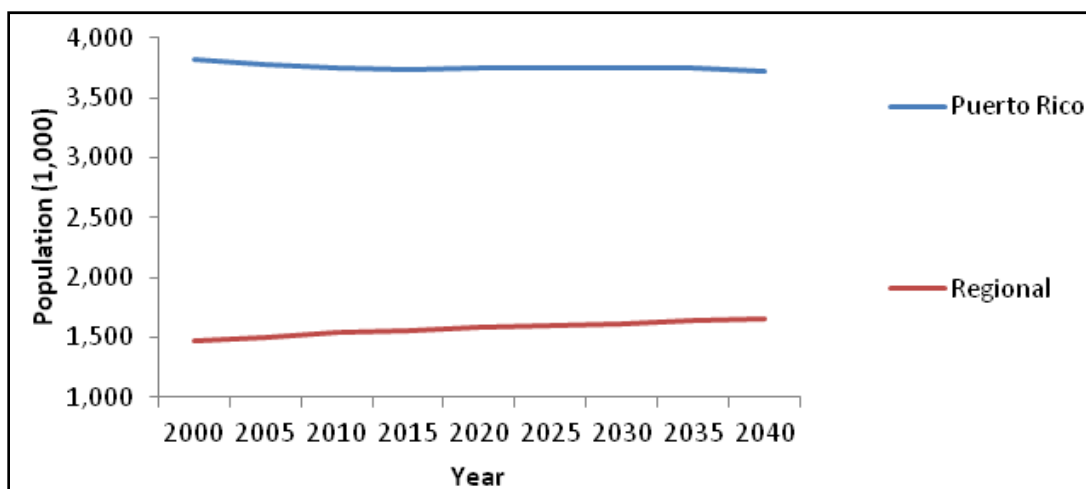
Puerto Rico's population has declined for the past few years (Puerto Rico Report 2013). The trend is expected to continue for the rest of the century (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat 2010). The drop is attributed to the island's limited job opportunities for recent university graduates. Recruiters for companies frequently visit the island to hire college graduates trained in

Science, Technology, Engineering, and Math disciplines (Nasser 2012). The unemployment rate is still over 14%, whereas at this writing, the US national average is slightly less than 8% (USBLS 2013).

The study region's population, in contrast to the overall island's population, is increasing as more people move towards the metropolitan area to find work (Figure 30). The number of jobs in the San Juan Metropolitan Area is projected to increase by 6.3% by 2030. Employment is expected to stay in the metropolitan core, but the population is expected to move to the suburban areas of San Juan (The Strategic Planning Office of the Puerto Rico Highway and Transportation Authority Department of Transportation and Public Works 2011). Table 4 lists water demand growth for Fort Buchanan's water region resulting from this population growth.

A 2005 baseline population for the region was derived from the sum of 2005 population data for municipalities in the PRASA metropolitan area (USGS 2012b).

Figure 30. Population growth projections.



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat 2010, USGS (2012).

Table 4. Population and water demand growth for Fort Buchanan's water region.

Year	Population	Population served by PRASA Systems	Withdrawals, in mgd					
			PRASA Surface Water	PRASA Ground Water	Total PRASA	Non-PRASA Surface Water	Total non-PRASA	Total PRASA and non-PRASA
2000	1,477,096	1,344,064	205.83	0.77	206.60	0.04	0.04	206.64
2005	1,505,072	1,369,520	209.73	0.78	210.51	0.04	0.04	210.55
2010	1,540,943	1,402,160	214.73	0.80	215.53	0.04	0.04	215.57
2015	1,552,413	1,412,598	216.33	0.80	217.13	0.04	0.04	217.17
2020	1,582,629	1,440,092	220.54	0.82	221.36	0.04	0.04	221.40
2025	1,596,149	1,464,227	224.23	0.83	225.07	0.04	0.04	225.11
2030	1,608,985	1,464,074	224.21	0.83	225.04	0.04	0.04	225.09
2035	1,640,399	1,497,730	229.36	0.85	230.22	0.04	0.04	230.26
2040	1,662,524	1,518,708	232.58	0.86	233.44	0.04	0.04	233.49
Absolute Change	185,428	174,644	26.75	0.10	26.84	0.01	0.01	26.85

Source: USGS (2012a), Luis Garcia Pelatti Consultoria (2008), pp 48, 69.

5.1.8 Issues

In addition to the sediment infilling of reservoirs, leaks cause significant stress on the potable water infrastructure's capacity to effectively transfer water. Puerto Rico's freshwater distribution system is very inefficient. For example, three separate leak investigations performed in 1960, 1987, and 1995, document water loss of 41%, 43%, and 42%, respectively, between when freshwater is withdrawn from public supply sources and delivered to consumers (Hunter 1995, Molina-Rivera 1998). PRASA estimates 60% of water is lost to leaks, theft, and illegal connections (Denis 2012).

5.2 Projecting water supply and demand trends in the Fort Buchanan regional model

Various scenarios were produced to review potential water scarcity issues to account for future uncertainty in water availability and consumption over the next 30 years. Unless otherwise noted, 2010 US Census data were used as a baseline to project to the year 2040 for regional population growth.

5.2.1 Scenario 1: Status Quo

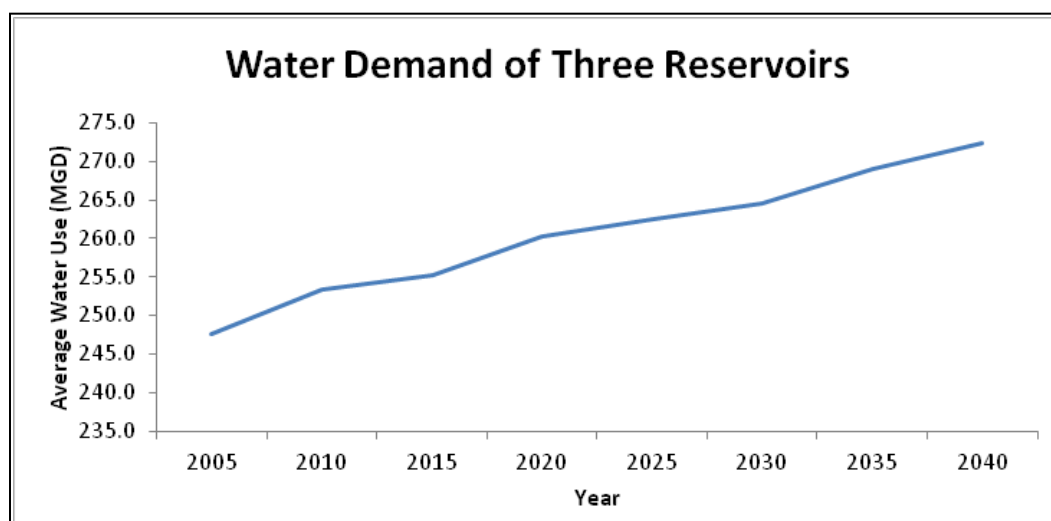
Scenario 1, the status quo scenario, supposes that no additional measures beyond current policies are established or implemented. Limits based on available water consumption data over the past 3 years and ASIP population forecasts for Fort Buchanan are used to create a water consumption trend line.

The average daily volume of water consumed is expected to increase each year through 2040 (Figure 31). The highest quantity of water used occurs in 2040 at just under 275 MGD. The maximum safe withdrawal rate from Lago Loíza, Lago La Plata, and Dos Bocas is 749 MGD. Regular dredging and consistent rainfall are required to maintain that rate. The maximum withdrawal rate is over 2.7 times greater than the maximum water consumption rate (not shown in Figure 31).

5.2.2 Scenario 2: Climate change leading to increased water demand and extensive sediment infilling in reservoirs

Scenario 2 (climate change leading to increased water demand and extensive sediment infilling in reservoirs) mimics a near worst-case climate change scenario in which water consumption increases and reservoir storage capacities diminish each year. Climate change can cause increased daily average temperatures, subsequently increasing agricultural, industrial, and personal water use. Climate change can also increase the frequency of extreme storm events, such as more intense hurricanes. An example of this occurred in 2010, a year that had fewer days of rain than average, but had 95 heavy rain events. Heavy rain events pushed the total rainfall in Puerto Rico to 132% of normal levels (Marino 2011).

Figure 31. Scenario 1: Status quo, regional water use based on population growth forecasts.



Reservoirs with large drainage areas (e.g., Lago La Plata and Lago Loíza) attract sediment over longer distances. This sediment requires more travel time and runoff to reach the reservoir. Although large drainage areas have the ability to store large amounts of eroded material, sizable tropical disturbances such as hurricanes can metastasize the material and flush it downstream to produce sediment infill for a reservoir.

Scenario 2 combines a 30% increase over average regional demand each year to account for greater water demand and an 8.7% annual decrease in the storage capacities of the main potable public water reservoirs for the region to account for sediment infill (Table 5). Annual sediment infill rate beyond 8.7% combined with a water consumption rate increase of 30% every year beginning in 2015 are the maximum rates that can be observed before water demand outpaces water supply in 2040. Beyond 2040, demand will still overrun supply at those rates.

5.2.3 Scenario 3: On-Site Well Usage

In Scenario 3, on-site well usage considers tapping groundwater reservoirs as an additional water source. The most feasible groundwater source would likely originate in an alluvial valley aquifer. Alluvial valley aquifers are a possible water source for Fort Buchanan given its location. Alluvial valley aquifers offer well yields that peak between 30 and 100 gpm (USGS 2009a).

Table 5. Scenario 2: Climate change leading to increased water demand and extensive sediment infilling in reservoirs.

Flow	Withdrawn in mgal/d						MGD Production
	Lago Loíza	Lago La Plata	Super Aqueduct	El Yunque	Other	MGD Demand	
Est. total annual flow	263.0	196.0	290.0	—	—	749.0	—
Est. % for region (2004)	39.7%	29.4%	19.3%	11.6%		100.0%	
2004	104.3	57.7	56.0	13.3	16.1	247.4	749.0
2005	104.4	57.7	56.0	13.3	16.1	247.5	749.0
2010	106.8	59.1	57.4	13.6	16.5	253.4	749.0
2015	107.6	59.5	57.8	13.7	16.6	331.9	683.8
2020	109.7	60.7	58.9	14.0	16.9	338.4	618.7
2025	110.7	61.2	59.4	14.1	17.1	341.3	553.5
2030	111.6	61.7	59.9	14.2	17.2	344.0	488.3
2035	113.4	62.7	60.9	14.5	17.5	349.8	423.2
2040	114.8	63.5	61.7	14.6	17.7	354.1	358.0

Although well-use will not completely alleviate the installation's water needs (Figure 32), it would lessen the base's overall dependence on PRASA. The cost of installing a well and filtering the water must be calculated to determine whether having a well is cost-effective. Irrigation offers an effective means to use water in a nonpotable setting and avoid higher costs of filtration, as well as to reduce Interlocal Agreement water use. The installation is currently tapping a well and installing a detention pond to irrigate the on-site golf course. A flow of 100 gpm would be required to meet the irrigation needs of the golf course (Johnson Controls 2011). The maximum expected yield of alluvial valley aquifers as indicated by USGS is 100 gpm.

5.2.4 Scenario 4: Well usage and conservation measures

Scenario 4 builds on Scenario 3 by implementing conservation measures on top of installing well systems. Conservation measures can include aerated water faucets, high efficiency toilets, and educational programs. This scenario assumes that those conservation measures will achieve a certain percentage of annual decrease in water consumption. Maximum well water withdrawal rates are estimated to be 0.144 mgd (Figure 33).

Figure 32. Scenario 3: On-site well usage, water usage forecast and possible well water yields.

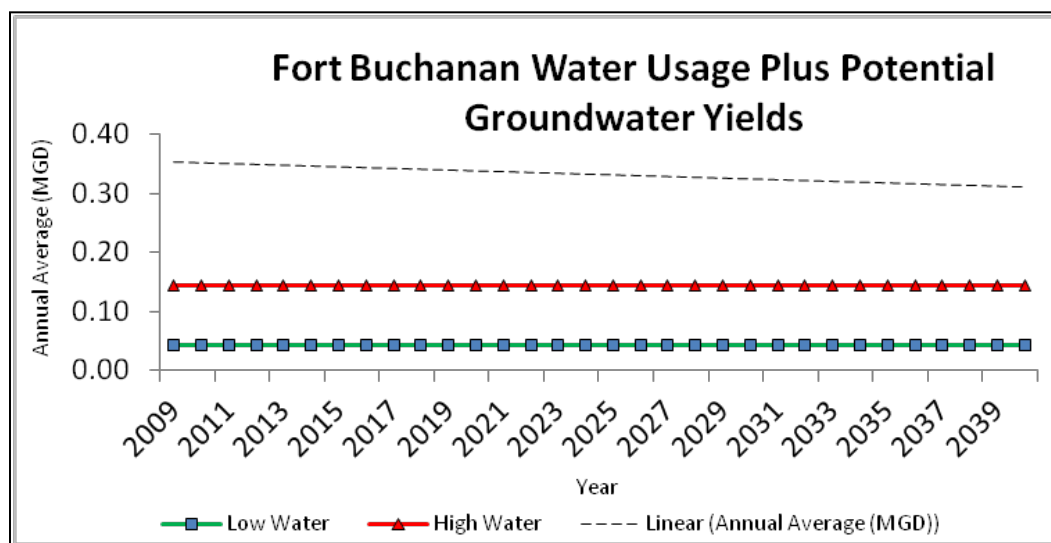
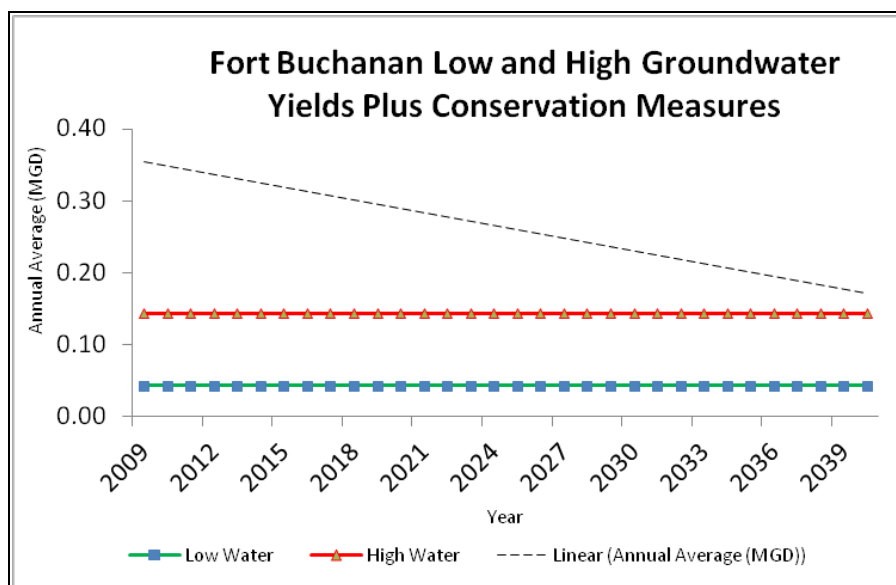


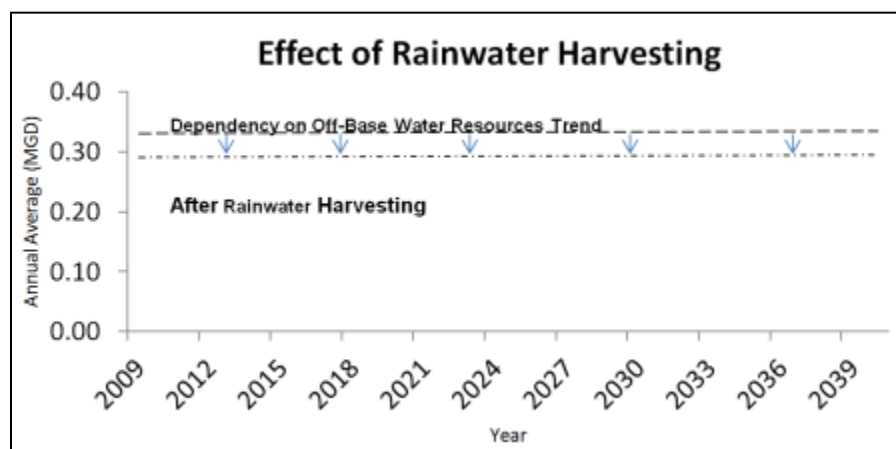
Figure 33. Scenario 4: Well usage and conservation measures well usage and a 2% annual decrease in water usage.



5.2.5 Scenario 5: Rainwater Harvesting

Scenario 5, rainwater harvesting, considers the benefits of rainwater harvesting (Figure 34). Harvesting rainwater decreases Fort Buchanan's dependence on water resources outside of the installation. Fort Buchanan's location offers a high annual rainfall average that yields nearly 14.5 million gallons per year or roughly 40 kgal per day from the nine buildings used to test the efficacy of capturing rainwater (Johnson Controls 2011). Rain does not fall every day so cisterns need be an integral part of rainwater storage so that sufficient water is available for later use.

Figure 34. Scenario 5: Rainwater harvesting.



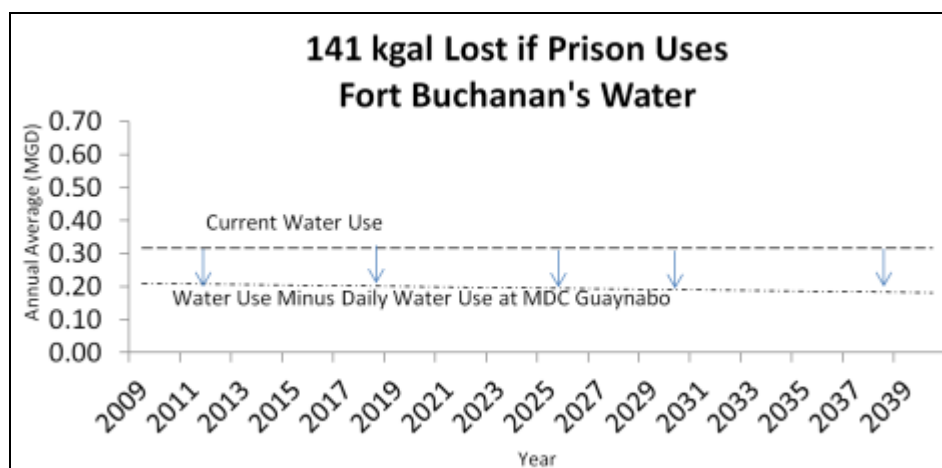
5.2.6 Scenario 6: Metropolitan Detention Center Sharing Same Water Line

Scenario 6 considers how much water would be lost if Fort Buchanan shared its water line with the Metropolitan Detention Center, Guaynabo (MDC Guaynabo). Interviewees in January 2013 expressed concern that MDC Guaynabo might share Fort Buchanan's water line since they shared the same water main in the past and because a correction facility would consume a high volume of water (Meeting, Round Table 2013). It is uncertain whether the shared pipe was ever severed or closed. If the two installations do share the same water line, then MDC Guaynabo would be siphoning approximately 141 kgal per day from Fort Buchanan or the equivalent of one-third (Figure 35) of Fort Buchanan's daily water consumption.*

5.3 Water sustainability assessment for the Fort Buchanan region

Puerto Rico's water supply and associated infrastructure is dependent on PRASA because of its extensive control over the island's water resources. For decades, PRASA's water infrastructure has faced challenges such as water theft, sediment infilling of reservoirs, and leaks that result in water loss of 40%. While dredging can alleviate some of the annual sediment buildup, extreme storm bursts caused by climate change can quickly set back dredging progress by metastasizing debris left in the areas surrounding reservoirs.

Figure 35. Scenario 6: Metropolitan detention center sharing same water line decline in water consumption if MDC Guaynabo is using Fort Buchanan's water supply.

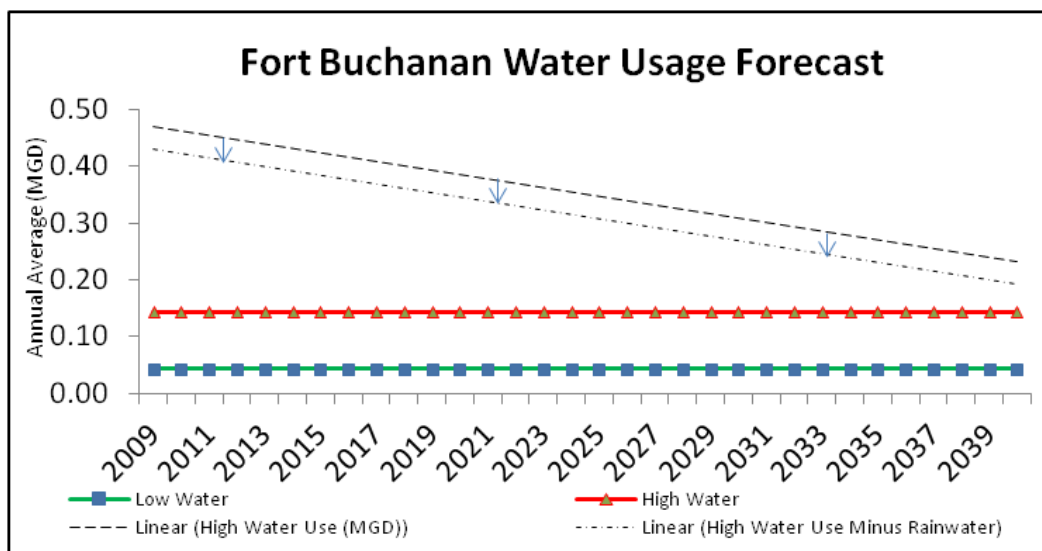


* MDC Guaynabo has a population of 1,725 (Federal Bureau of Prisons 2013). One prison inmate uses approximately 82 gal/day of water (Yáñez-Correa and Laurin 2011).

Fort Buchanan has several options to help minimize its dependency on outside water resources (Figure 36). Fixing the existing leaking water distribution is the first option because it would greatly raise the efficiency of the system. The second option involves pumping groundwater. Treating water to make it drinkable can be a costly task. Fort Buchanan plans to draw groundwater for golf course irrigation. The third option would take advantage of the high precipitation rate at Fort Buchanan to subtract roughly 40 kgal from their water bill.

Fort Buchanan will unlikely be able break its reliance on PRASA-supplied water any time soon. Fostering greater collaborative efforts with PRASA is therefore in Fort Buchanan's best interest. Such efforts may include teaming up to create dredging schedules, to provide technical expertise, and to promote leak deterrent methods to fortify the water distribution system of the region. Strengthening the collective efforts between PRASA and the installation will not only help the long-term sustainability of the region, it will minimize the vulnerabilities of Fort Buchanan.

Figure 36. Selected scenarios combined.



6 Camp Rilea

Camp Rilea (Figure 37) is located between the cities of Warrenton and Seaside, along the North Coast region of Oregon (Figure 38). Since it was established in 1927, the Oregon National Guard has been present on this site although the installation's mission has changed over time. Today, Camp Rilea Armed Forces Training Center is operated by the Oregon Military Department, which provides training for units of the National Guard, the Air National Guard, and US active duty forces, and hosts a variety of civilian and recreation activities (Pike 2013). Camp Rilea is also an emergency response center for Clatsop County and other counties within the region (Arnold 2012).

6.1 Regional definition

The Clatsop Plains is an area of approximately 40 square miles on the northern coast of Oregon. The region is characterized by narrow strips of vegetated dune ridges that run parallel to the coastline from the Columbia River south to Tillamook Head. The plains are bounded by the Pacific Ocean on the west and the foothills of the Oregon Coast Range to the east (Coles 2005, Frank 1970). For the purposes of this study, the region is defined by the Clatsop Plains aquifer (Figure 39).

Figure 37. Entrance to Camp Rilea.

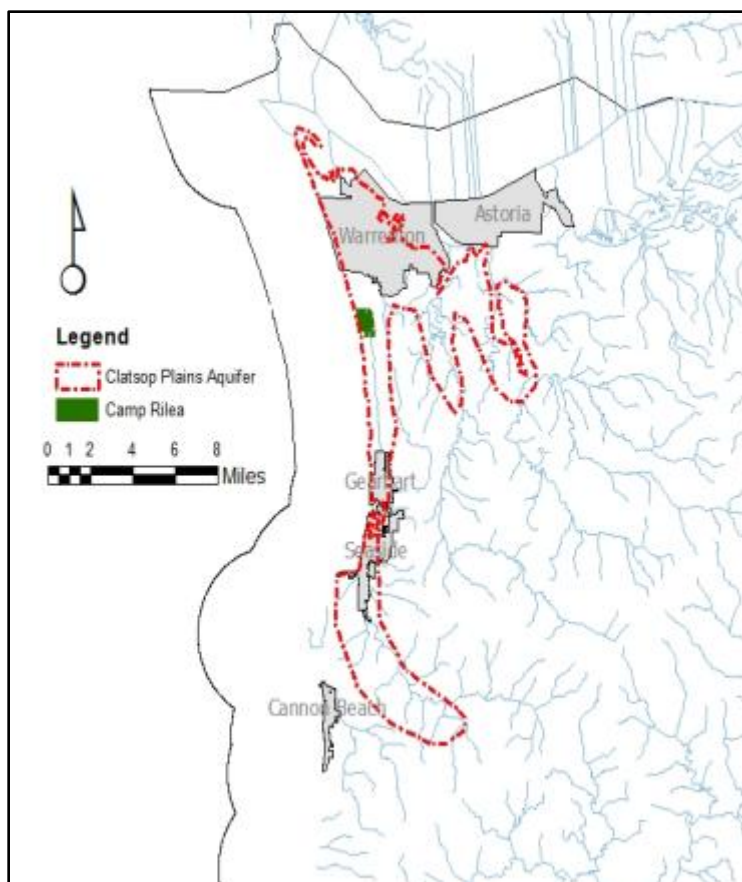


Figure 38. Location map of Camp Rilea.



Source: Site atlas.com

Figure 39. Map of study region with municipalities.



6.1.1 Demographic trends

The largest cities located within the study region are Warrenton, Gearhart, and Seaside. The 2010 census reported Warrenton's population as 4989, a 21.8% increase from the 2000 census (US Census Bureau 2000, 2010). The City of Warrenton is the location of economic and commercial activities within the study region. Recently, urban development has increased on the edge of the City near Camp Rilea.

Although the City of Astoria is not located in the study area, it is regionally significant because it is the largest city in the region and also a regional job and cultural center. Astoria's growth is constrained because of its location on the Columbia River and the surrounding steep terrain. Warrenton is located directly west of Astoria. Based on Warrenton's topography, available land, and desire for growth, it is assumed that much of projected regional growth will occur within Warrenton's growth boundary, as it is much more favorable for infrastructure expansion necessary for urban development.

The coastal communities of Gearhart and Seaside experience a population surge during the summer months because of their role as vacation destinations. The 2010 census for Gearhart reported a population of 1462, a 46.9% increase from the 2000 census (US Census Bureau 2000, 2010). Seaside, the largest city in the study area with 6457 people, experienced the least amount of population growth at 10% (US Census Bureau 2010).

6.1.2 Water sources

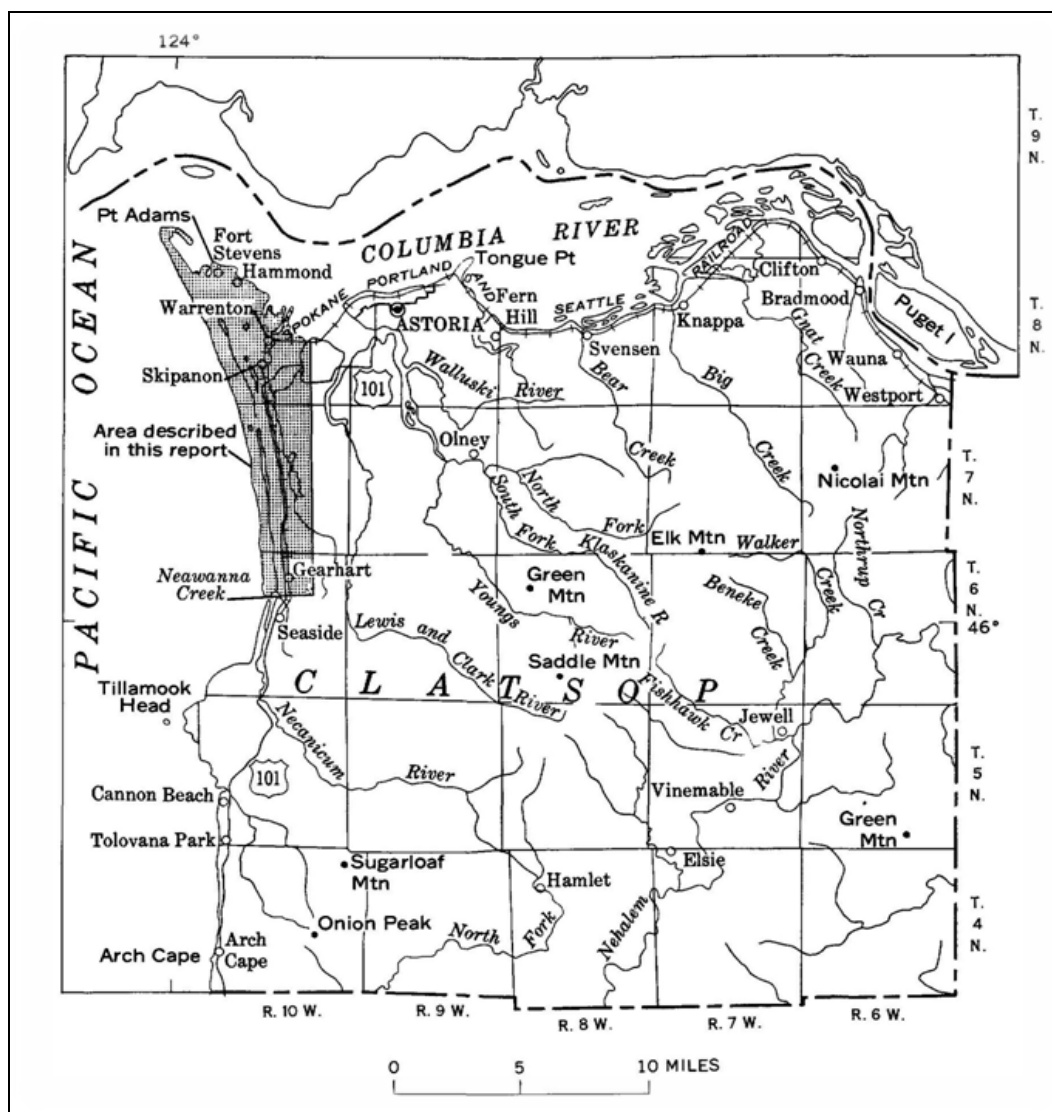
Camp Rilea recently constructed an independent water supply system that includes two groundwater wells, a water treatment plant, and a storage reservoir. Before the construction of the new system, Camp Rilea purchased its water from the City of Warrenton (Kennedy/Jenks Consultants, 2009). The purpose of securing an independent water source was based on the installation's mission as an emergency response center. In the event the water source is not available or becomes compromised, the installation's backup source is the City of Warrenton (Arnold 2012). The groundwater system at Camp Rilea withdraws water from the Clatsop Plains aquifer to provide potable drinking water and fire suppression to the installation. The nearby City of Gearhart recently constructed a new water supply system withdrawing water from the same aquifer (Gearhart Water Treatment Plant Operator 2012). Gearhart is the only other public system withdrawing from the aquifer and also subject to state beneficial use requirements.

Although there is not an extensive mapping of this groundwater system, the most commonly referenced study is a 1970 US Geological Survey, which provides a description of the aquifer (see Figure 40). The Clatsop Plains aquifer has distinct characteristics based on its underlying soil composition and geology. In areas underlain by Tertiary bedrock, the soil has low permeability, and can store and yield small quantities of groundwater. In the lowland areas, the region consists of dune and permeable beach sand that absorbs a large percentage of precipitation (Frank 1970).

6.1.3 Water rights and regulations

In Oregon, all water is publicly owned and is subject to the principles of prior appropriations. In most cases, all water users must establish rights before withdrawing water. Different from riparian water rights, water on adjacent land is not automatically allocated to property owners.

Figure 40. Frank's study area.



To obtain water rights, applicants must first apply to the Department of Water Resources for a permit to withdraw water. If the permit is granted, the applicant is authorized to construct the system and begin withdrawals. For compliance, the permit holder must complete a survey to demonstrate the application of water use. A water right certificate is issued if it is determined that water is used in accordance with the permit. This water certificate must be exercised for beneficial use (Johnson 2009). According to state law, all water must be put to beneficial use; however, not all water uses qualify as "beneficial," as it implies water is used without wasting any of it. The failure to exercise water rights for a period of 5 continuous years in any 15-year period can result in revocation of the water right (Department of Water Resources 2009).

On 16 November 2006, the Oregon Water Resources Department issued Camp Rilea a Permit to Appropriate Public Waters. Withdrawal rates in the permit are constrained during the dry season from July through October (Table 6). Construction of the water supply system was completed by October 2011 and an application for extension of time was submitted to demonstrate complete application of the water. Complete application of the water will be demonstrated by 2019 followed by a claim of beneficial use recorded by a Certified Water Rights Examiner.

6.1.4 Climate

The climate in the North Coast Basin is generally mild and wet. Temperatures along the coast vary from lows of about 36 °F to highs around 72 °F. The months of July, August, and September tend to be the warmest, but average summer temperatures are only about 15 degrees above the coldest month, January (Coles 2004, Oregon Climate Service 2012). Rainfall varies along the coast due to the orographic effects of the coastal mountains, ranging from 60 to 90 in. per year. This is a result of prevailing winds from the west bringing moisture from the Pacific Ocean. As moisture builds up against the Coast Range Mountains, the moisture condenses and the clouds release the moisture as large amounts of rain and snow. The study region is estimated to receive 70 to 80 in. of rainfall annually (Oregon Climate Service 2012).

Based on records of the 20th Century, the region has experienced an increase in temperature and precipitation over the last century. Annual temperatures have increased by 1 to 3 degrees Fahrenheit with an annual increase in precipitation of 10%. However, there are variations in this pattern as warmer years experience drier conditions and cooler years are wetter (Oregon Climate Change Research Institute 2012).

Table 6. Water rights belonging to Camp Rilea.

Time Period	Flow Rate (CFS)	Flow Rate (gpm)
1–30 June	0.668	300
1–31 July	0.443	199
1–30 August	0.289	130
1–30 September	0.410	184
1–31 October	0.485	218

Climate change will impact the seasonality of precipitation in the region with more dramatic changes occurring in the winter months. This includes increased amount of winter precipitation falling as rain rather than snow, increased winter stream flow, and winter floods. These projections reduce the amount of water stored as snow, particularly in mid-elevation rain/snow mix basins. Changes in the spring will result in earlier snow melt, shifting and decreasing late spring and summer stream flows (Oregon Climate Change Research Institute 2012).

Climate change is expected to contribute to sea level rise. Globally, the mean sea level has risen by 25 cm on average over the last century and is projected to rise another 50 cm by the year 2100. Groundwater sources, particularly coastal aquifers, are vulnerable to this sea rise because of saltwater intrusion and salination of groundwater (IPCC 2007). On the Oregon coast (Figure 41), the potential sea level rise is up to 3 ft (NOAA 2012). The low-lying areas that are currently vulnerable to flooding may be at risk for significant flooding, adversely impacting fresh groundwater sources.

Figure 41. Potential coastal flooding near Camp Rilea.



Source: NOAA 2012

6.1.5 Topography/Geology

Topography in the Clatsop Plains is characterized by flat lowland bordered by rolling hills and sand dunes that rise 10 to 100 ft above sea level. The sand dune ridges slope upward from the ocean to the base of the bedrock foothills. The highest points of the dune ridges, southwest of Warrenton, reach elevations of around 100 ft (Frank 1970). In the lowland area, historic floodplains have been drained to facilitate development. The Clatsop Plains is a complex of unconsolidated dunal sands from 125 to 400 ft thick with underlying sedimentary rocks of shale and sandstone (Coles 2004).

6.1.6 Land use/land cover

Land use in the larger North Coast Basin area (Figure 42) consists of 84% forest land, 7% urban, commercial, or industrial; 5% crop, pasture, or range; about 3% estuary; 1% residential, and less than 1% sandy areas or rock/gravel mining (USGS 2003). However, based on the more defined study area, a large portion is urban development and woody wetlands (Figure 43).

Figure 44 shows an example of the type of urban development being constructed in the aquifer. This example is a 75-acre development is known as the North Coast Retail Center, located on Highway 101 in Warrenton (Myriad Commercial Properties 2013). Similar developments are located in the vicinity. The change of land cover to impervious surface has the potential to alter the groundwater recharge.

6.1.7 Historic water demand

Based on 2005 USGS data, historic water withdrawals for Clatsop County are primarily from surface water at 57.48 mgd while the groundwater withdrawals are 0.34 mgd (Table 7). These estimates of water withdrawals are categorized as public supply, self-supplied domestic, industrial, irrigation, mining and aquaculture at the county level. Based on county level data, public supply and domestic, self-supplied water use account for a significant amount of the groundwater withdrawals (USGS 2005). The historic pattern of water use within the county consistently relies on surface water more than ground water, although there has been fluctuation in consumption throughout the years (USGS 1985-2005).

Figure 42. Land cover/land use.

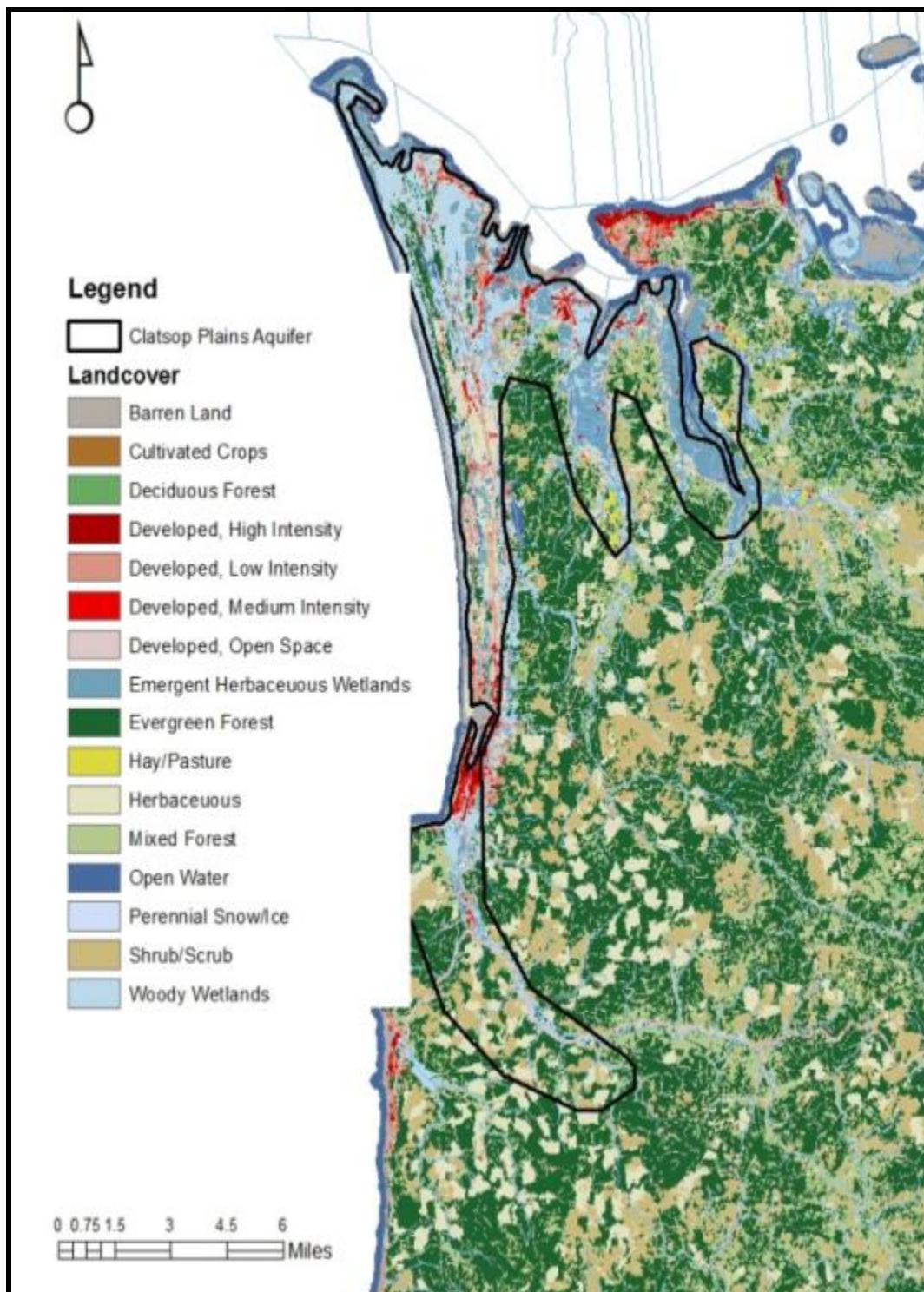


Figure 43. Wetland at Camp Rilea.



Figure 44. Big box development in the aquifer.



Source: Myriad Commercial Properties 2013

Table 7. Historic Water Use for Clatsop County (1985-2005).

	1985	1990	1995	2000	2005
Groundwater	0.91	0.69	0.69	0.13	0.34
Surface Water	47.16	104.02	119.39	46.37	57.48
Source: USGS (1985-2005) Water Use Data					

6.2 Developing the Camp Rilea regional model

Camp Rilea obtains its potable water from the Clatsop Plains aquifer via two recently constructed wells located on the installation (Figure 45). Based on well logs, the well sources on the installation provide about 7 million gallons of water per year. The installation serves a population of 125 full-time civilian staff and an average transient population of 1200 (Kennedy and Jenks Consultant 2011). The transient population fluctuates depending on unit training and other activities occurring on the installation. During the summer months, the installation experiences an increase transient population up to 3400 in unit training and visitors (Kennedy and Jenks Consultant 2011, PNNL 2012). During this peak time, Camp Rilea's water permit places greater restrictions on water withdrawals.

Figure 45. New well construction at Camp Rilea.



6.2.1 Water supply model

6.2.1.1 Description

The complexity of groundwater systems makes it difficult to accurately project the amount of water available for water supply as the aquifer system is dependent on geology, climate, physiographic and consumptive patterns of the area. Based on a previous study, the Clatsop Plains aquifer may have 2500 acre-ft of groundwater per year per square mile for a 10 square mile area that is most favorable for development. This area includes the central part of the dune area, where the groundwater reservoir is thickest and absorbs and stores the most precipitation. Camp Rilea is located within this part of the aquifer. It is estimated that, in this part of aquifer, the sand dune area has a water level sufficiently high above sea to prevent sea water intrusion. Well testing information determined the area is capable of yielding 100 gpm (Frank 1970).

6.2.1.2 Drivers for water supply

The balance calculations for the aquifer are based on inputs and outputs of the hydrological system. Aquifer input includes precipitation, which accounts as the primary mechanism for recharge. It is estimated that the area receives about 70 to 80 in. of rainfall annually. About 80% of the precipitation infiltrates through the highly permeable sandy soils into the aquifer's dune sand. Minor aquifer recharge comes from irrigation and domestic source with little contributions of surface water runoff from the Coast Range foothills. Other stream flow contributes to the aquifer. Outputs include discharges into the Columbia and Necanicum Rivers (Figure 46) and the Pacific Ocean, evapotranspiration of open water and land surfaces, and water consumption (Coles 2004, Frank 1970).

Numerous lakes and wetlands are present in the area and are highly interconnected to the groundwater system. The presence of these lakes is a result of the water table at the surface. The major lakes in the area include Smith, Sunset, and Cullaby Lakes (Figure 47). There are only a few streams within the coastal dune area, including Neacoxie Creek (Figure 48), which flows into Sunset Lake, and an unnamed stream that flows into the Skipanon River (Frank 1970).

Figure 46. Local watersheds.

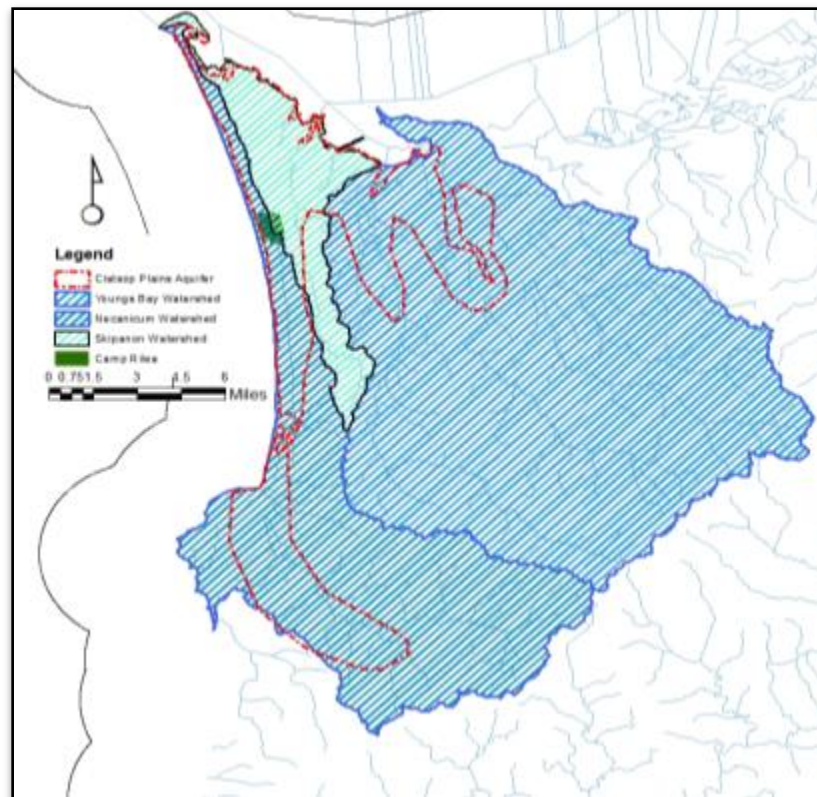


Figure 47. Surface water connections.

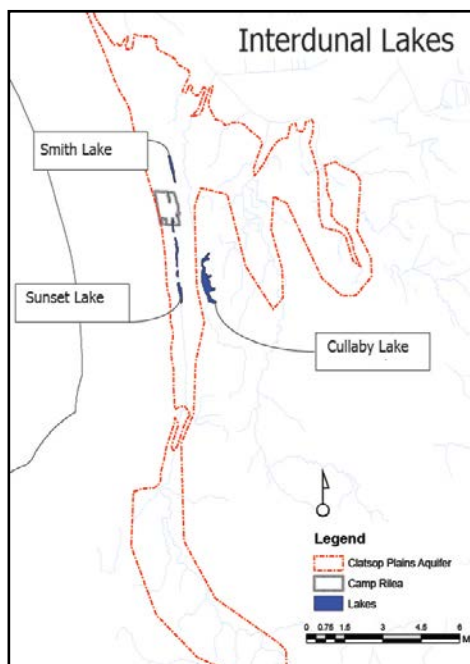


Figure 48. Neacoxie Creek near Gearhart, OR.



The permeability of the sand aquifer allows for quick absorption of the precipitation that falls in the region. It is estimated that the permanent groundwater table occurs at 3 to 33 ft below ground surface. The greatest amount of evaporation occurs between June and August (Frank 1970), which also coincides with the least amount of rainfall and region's highest seasonal population.

6.2.2 Water demand projections

The water demand projections consist of a regional demand analysis based on the study region and Camp Rilea (Table 8). The baseline is determined by known area consumption data and population projections for the study region. It assumes that total withdrawals will increase at the same rate as population, and projects water demand through 2040.

The water demand model uses historic consumption data (Figure 49), real property data, and information (PNNL 2012, Kennedy/Jenks Consultant 2005, 2009, 2011, 2012). These reports contain current and anticipated population and future water demand for the installation. Fluctuation of water demand occurred in the last decade with a steady rise from 2002 to 2006. There was a slow decline in water use after peaking in 2006 (Kennedy/Jenks Consultants 2009).

The Camp Rilea water demand model has multiple inputs that were used to calculate baseline installation water use (Table 9). The model incorporates real property data by using category codes to determine the total number of buildings, primary and secondary quantities, and square footage. The input labeled "barracks" includes the number of beds available on the installation, which was taken from the real property data.

Table 8. Current water demand for groundwater within the study region.

Name	Average MGD	Highest MGD
Camp Rilea	0.02	0.09
Gearhart Water District	4.5	16
Sunset Lake Recreational Vehicle (RV) Park	0.003	0.006
Total	4.523	16.096

Figure 49. Historic water demand at Camp Rilea.

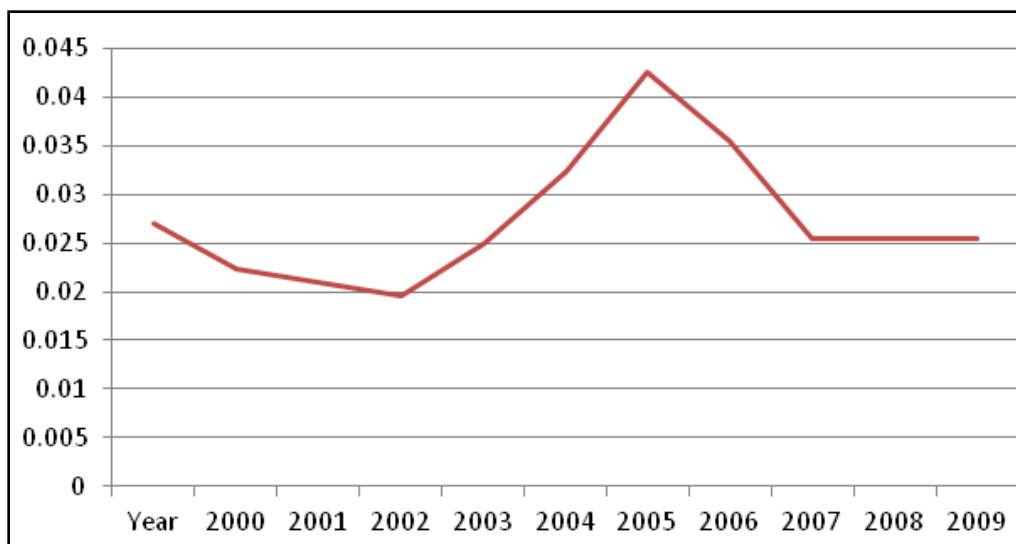


Table 9. Camp Rilea installation water demand model inputs.

Model Inputs	Baseline Value
Barracks	1,200
Military Stationed	2
Transient Population	3,450
Dependents	0
Civilian Workforce	125
Deployment Factor: Family Housing	0.00
Deployment Factor: Barracks	0.10
Industrial/Maintenance Factor	1.00
Storage Growth Factor	1.00
High Water Use Facilities Factor	1.00
Irrigated Land Factor	1.00
Losses Factor	1.00
Moisture Deficit Factor (in)	15

6.2.2.1 Camp Rilea demand projections

Transient population and civilian population estimates were derived from the PNNL (2012) and Kennedy/Jenks (2005, 2009, 2011, 2012). Transient population consists of National Guard units that use the installation for training, visitors using lodging facilities, and contractors. Civilian workforce includes full-time personnel with off-site residency. Military station represents full-time personnel with on-site residency.

Deployment Factor represents the average barracks occupancy level. Based on occupancy information (PNNL 2012), the deployment factor for the barracks is 0.10, which means that 10% of the barracks is occupied over a year. Other factors such as industrial/maintenance, storage growth, high water use, irrigated land, and losses are set to 1.00, which maintains current level of intensity. The moisture deficit factor is the local evapo-transpiration rate, an annual loss of 15 in. of surface water.

The model uses estimated consumption in gallons per unit per day by the type of facility. The unit varies. For example, for barracks, administration, lodging, medical, and commercial, the unit is per capita. For industrial/maintenance and storage, the unit is the building. Per-capita use is based on estimates (PNNL 2012) (Table 10). Based on these inputs, the baseline annual use for Camp Rilea is 0.02 MGD. This estimate is slightly less than historic consumption patterns and very close to 2011-2012 well production data maintained by the installation. It is assumed that Camp Rilea will comply with EO 13514, which mandates 2% reduction in water usage for Army installations each year through 2020 (Figure 50).

The regional demand baseline for the study area uses 2005 estimated water consumption for Clatsop County as the study region is located entirely in the county (USGS 2005). The model includes entities drawing on groundwater as their water supply and does not include surface water withdrawals. The estimates for the study region are weighted by a percentage of the population living in the region, which is derived from 2010 Census Tract data files. This growth is extrapolated from the population projections for Clatsop County (Population Research Center at Portland State University 2012). The regional projection assumes that all water demand will grow at the same rate as population. Growth, which is expected to be modest (Figure 51), will be characterized as mostly residential, with some commercial. Based on the regional economic climate, industrial growth is not expected to occur at the same rate as other land uses.

Table 10. Baseline water consumption by unit.

Consumption (gpd)	Baseline Value
Family Housing	0
Barracks	65
Dependent Schools	0
Medical	10

Consumption (gpd)	Baseline Value
Industrial/Maintenance	300
Lodging	65
Admin/Moderate Users	20
Community and Commercial: Non-food related (indoor)	20
Community and Commercial: Food related	20
Storage	8
High Water Use Facilities	80

Figure 50. Reduction based on EO 13514 water reduction targets.

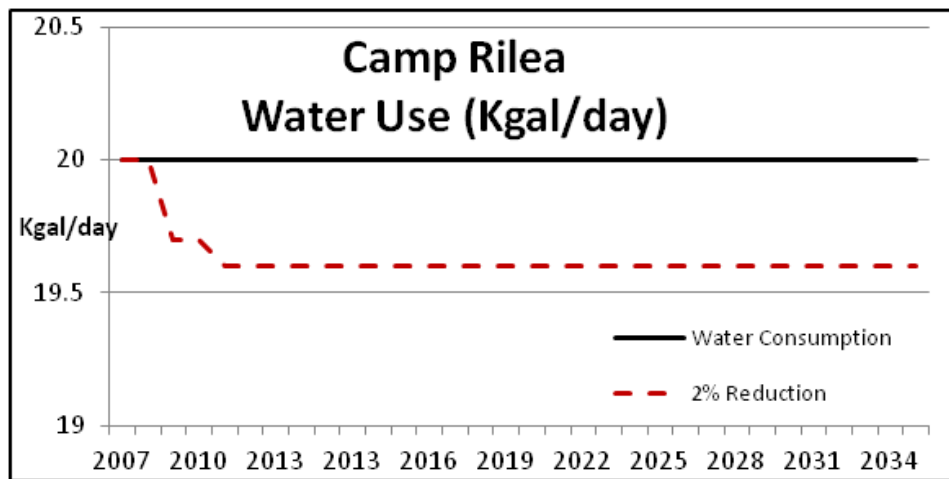
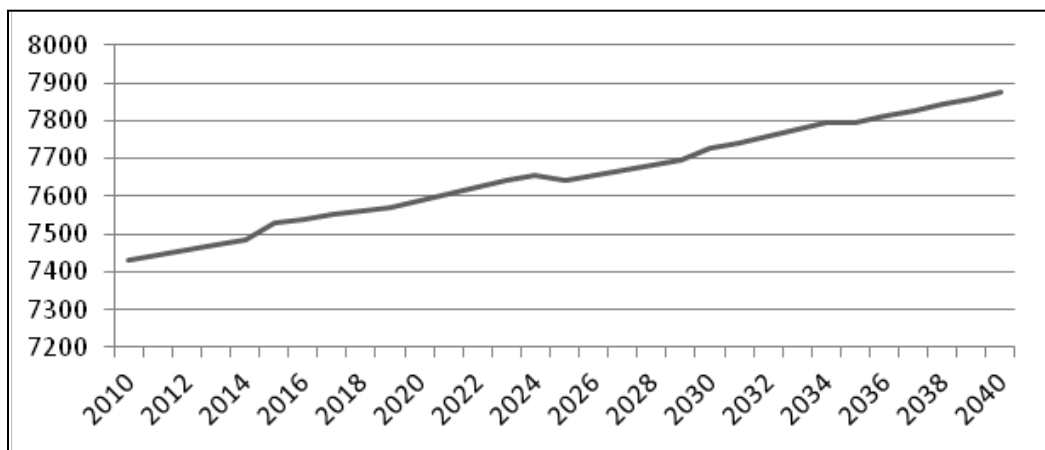


Figure 51. Regional population growth.



6.2.2.2 Regional water demand projections

The only public system using groundwater in the study region is the City of Gearhart. There are many private wells in the area used for irrigation, agriculture, aquaculture, and domestic uses. Demand for groundwater has been increasing over time and is expected to continue (Table 11).

Table 11. Projected regional groundwater demand.

	2012	2015	2020	2025	2030	2035	2040
Regional Study Area (MGD)	13.8	14.2	14.9	15.7	16.5	17.3	18.1

Water rights permitting data approximately shows 298 wells located in the aquifer (Oregon Water Resource Department 2012). Although it provides location and historic water rights, it does not include accurate withdrawal information.

Projected regional water consumption assumes a continuation of population growth in Gearhart and areas within the aquifer. The location of numerous private wells within the aquifer allows for domestic and agricultural consumption. At present, these wells may not pump at full capacity; however, water rights have already been established; therefore groundwater withdrawals could increase.

Camp Rilea 2040 water availability scenarios

The objective of the study is to project future water availability based on a set of potential conditions that the area may experience. Therefore, the end state for water supply and demand projections is 2040.

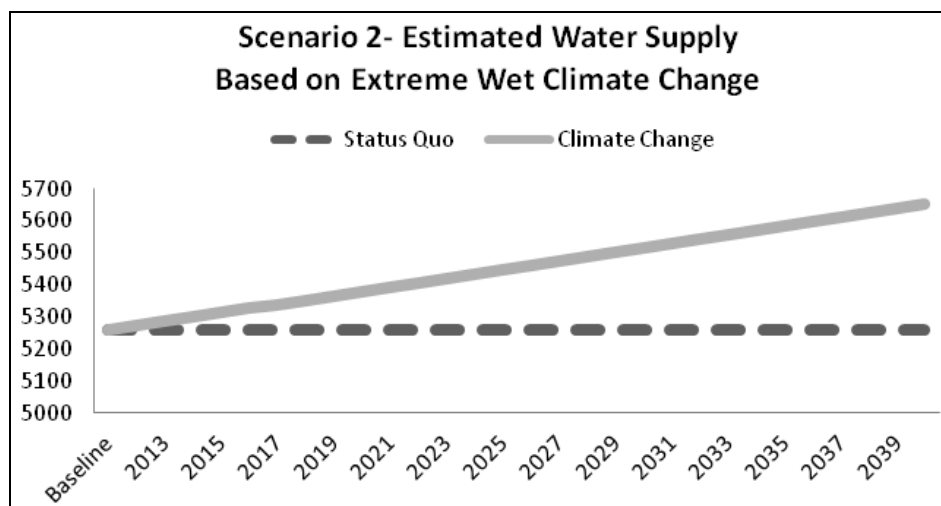
6.2.2.3 Scenario 1 – Status Quo

Scenario 1 assumes that existing conditions of consumption, precipitation, and population growth will continue. It also assumes that aquifer recharge will remain constant and a slight increase in demand based on Camp Rilea and other groundwater users in the region. Climate change is assumed to have minimal effects on water supply or demand. This scenario assumes that there is a slight increase in precipitation and evapotranspiration, which result in a slight gain in the water supply with 1.2 in. of annual recharge.

6.2.2.4 Scenario 2 – Climate Change (Extreme Wet)

The climate change scenario is based on projections from the Oregon Climate Change Research Institute (2012). Scenario 2 assumes a 15% increase of precipitation, which is slightly higher than recent records indicate. Based on the increase of precipitation despite the increased temperature/evapotranspiration, the aquifer recharge should increase annually by 10.25 in. (Figure 52).

Figure 52. Extreme wet conditions.



6.2.2.1 Scenario 3 – Climate Change (Extreme Dry)

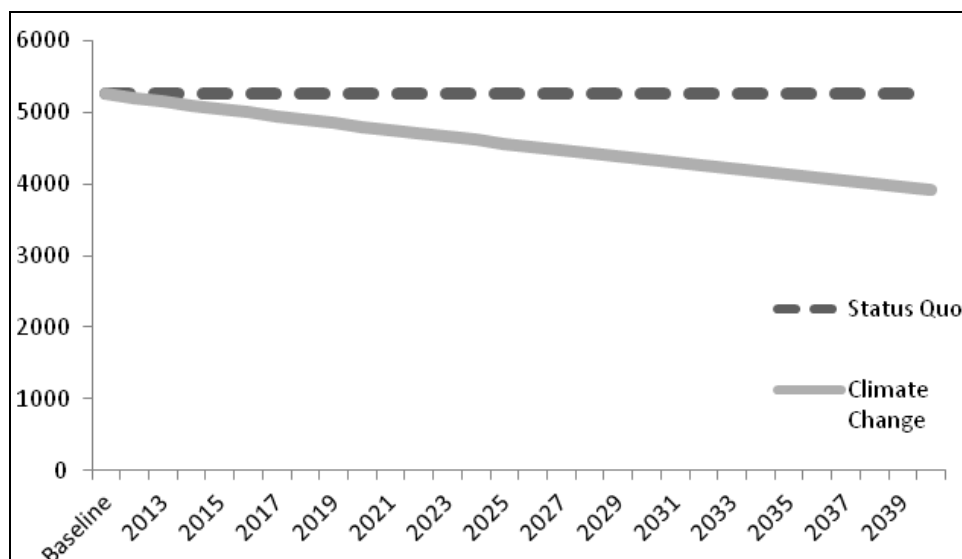
Scenario 3 assumes a 2% aquifer water loss each year based on extremely dry summers. Although climate change projections include a higher concentration of rainfall during the winter, the model assumes a loss in aquifer recharge due to extremely dry conditions during the summer. Based on the characteristics of the aquifer, there are limitations to its storage capacity that will reduce the availability of water during periods of highest demand. Higher temperature will affect evaporation and increased impervious area will increase runoff.

Under these conditions, it is estimated that there will be an annual loss of 7.5 in. in aquifer recharge. Despite the increase in precipitation, the aquifer recharge is estimated to decrease by about 12% by 2040 (Figure 53).

6.2.2.2 Scenario 4 – Increased Demand

Scenario 4 assumes an increased demand based on the conversion of seasonal population to permanent population, the potential for other cities withdrawing water from the aquifer, and the potential for growth in regional development. For example, the City of Gearhart reports 1,400 permanent water connections in its system, but during the summer it estimates that the city serves up to 10,000 users (Gearhart Water Treatment Plant Operator 2012).

Figure 53. Estimated water supply based on extreme dry conditions.



There is also a potential for growing demand from private resorts and commercial development along the coast. Although the City of Warrenton does not pump water from the aquifer, much of Warrenton's potential developable land is located within the study area. Increased urban development could significantly negatively affect the amount of aquifer recharge.

For this scenario, change in regional population between 2010 and 2040 is assumed to be 10% higher (Figure 54) than currently projected, which can increase demand for water (Figure 55). For the installation, the increase in the permanent or transient Soldier population may not be currently planned, but increases in other civilian activities may affect the demand for water on post. Likewise, the installation mission as an emergency response center may expand as climate change increases the frequency of wind storms, flooding, and fires. It is assumed that precipitation patterns will stay the same, but the amount of surface runoff and evapotranspiration will both increase. Based on these conditions, the potential for annual aquifer recharge loss is estimated at 0.4 in.

Figure 54. Estimated regional population growth for increased demand scenario.

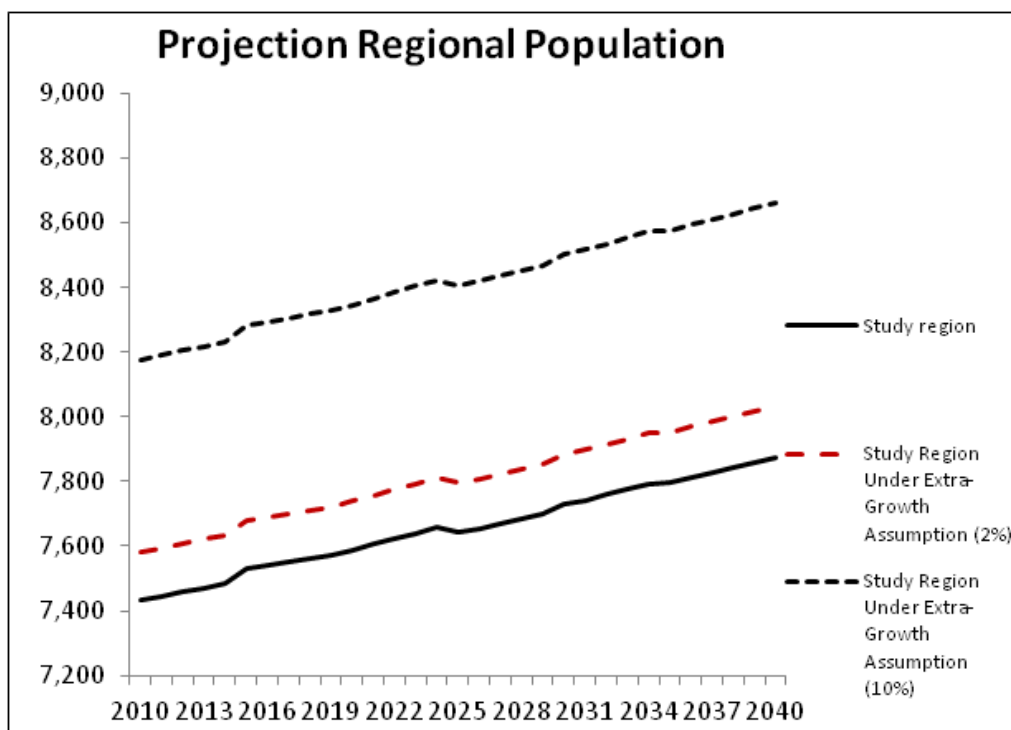
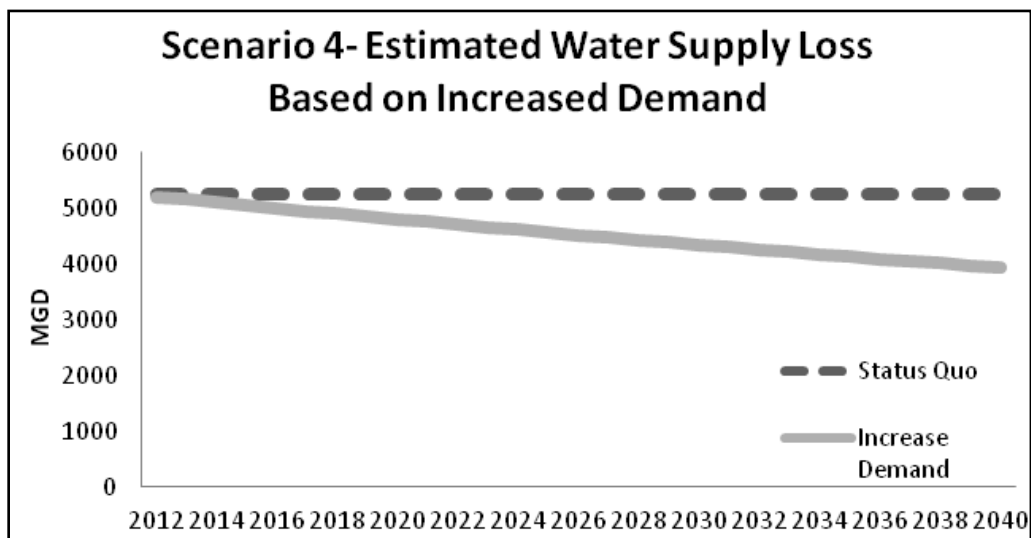


Figure 55. Impacts to water supply based on increased population.



6.2.2.3 Scenario 5 – Water Efficiency

The State of Oregon requires public water suppliers to submit water conservation plans for approval. Part of the approval process includes periodic reports on how the suppliers will achieve the goals stated in the plan. If it is determined that the suppliers cannot meet the conservation and man-

agement goals, the state can place water restrictions and, in some cases, revoke a water rights permit (Oregon Water Resources Department 2009). Both Camp Rilea and the City of Gearhart, the only two public suppliers in the study area, have submitted conservation plans to the state, which include the following elements (Kennedy and Jenks Consultants 2011, 2012):

- full system metering
- meter testing and maintenance
- annual water audit
- leak detection program
- leak repair and replacement program
- public education
- reuse and recycling
- rate structure and financial.

Camp Rilea has already begun an extensive wastewater reuse and recycling program with the construction of rapid infiltration basins and a recycled water treatment plant. Several pipes have already been installed that use recycled water for landscaping and other irrigation needs around the installation. Camp Rilea plans to extend the system and connect additional piping for irrigation using the recycled wastewater. The use of the recycled water recharges the aquifer. Under the water efficiency scenario, it is estimated that the aquifer has the potential to annually gain 8.4 in., which would be a gain in groundwater recharge (Figure 56).

6.2.2.4 Scenario results

With the absolute amount of groundwater available in the Clatsop Plains aquifer region relatively unknown, the water supply model calculates the estimated recharge based on varying conditions. Under different scenarios, the aquifer's supply fluctuates resulting in a surplus or deficit (Table 12). If the region experiences extremely dry conditions and population growth, then the risk to the aquifer from depletion is higher. Increased population growth and urban development have the potential to increase the water demand, but the increase in the amount of impervious surface could significantly affect aquifer recharge as well.

Figure 56. Water efficiency programs.

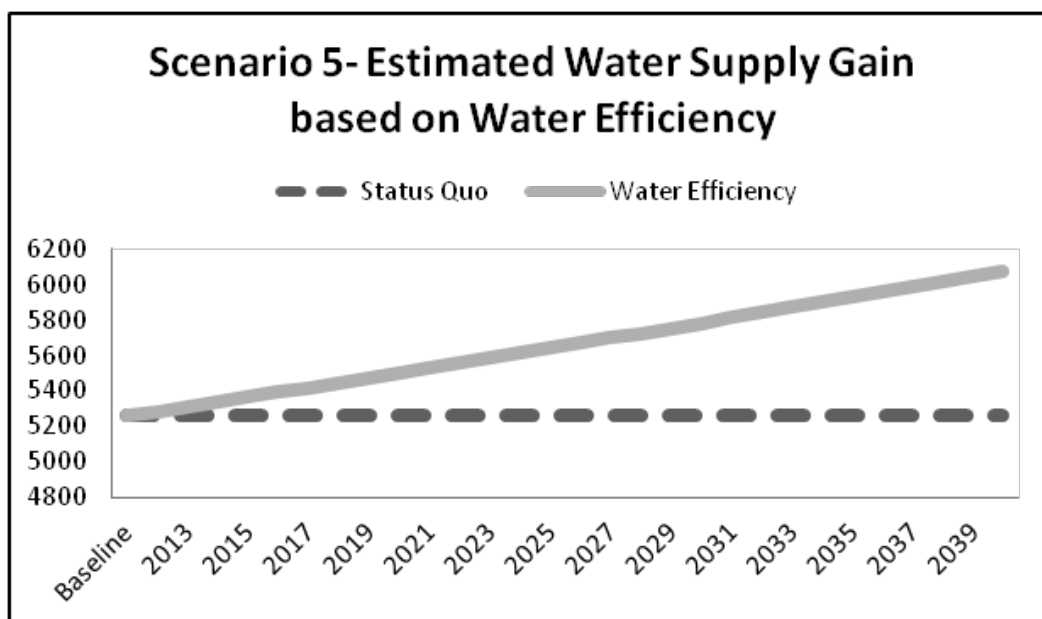


Table 12. Scenario results.

Parameter	Baseline	Scenario 1 Status Quo	Scenario 2 Climate Change (Wet)	Scenario 3 Climate Change (Dry)	Scenario 4 Increased Population	Scenario 5 Water Conservation
Aquifer Recharge	60	61.2	71	52.5	59.6	68.4
Withdrawals, Camp Rilea	0.2	0.196	0.196	0.196	0.196	0.196
Region	13.86	15	15	15	16.7	13.6
Yearly Gain Aquifer Supply	...	1.2	10.25	-7.5	-0.4	8.4

Extremely wet conditions caused by climate change may have a positive effect on the recharge of the aquifer. Despite increased temperatures and evapotranspiration, the water supply has the potential to increase due to higher amounts of precipitation. However, the rate in which rain falls will determine how much is absorbed into the aquifer system. Increased heavy downpours will result in substantial surface runoff. For both wet and dry scenarios, climate change is likely to have a strong effect on saltwater intrusion due to projections for sea level rise. Besides increased precipitation, increased water efficiency through water recycling and reuse, has the greatest potential for maintaining and even increasing groundwater recharge.

6.3 Water sustainability assessment for the Camp Rilea region

Continued water availability in the Camp Rilea study region will depend on increased demand, climate change, and the effectiveness of region-wide

conservation efforts. Based on known characteristics of the aquifer, groundwater is replenished regularly by the natural hydrological cycle. The abundance of rainfall and quick absorption of the shallow, dunal aquifer currently maintains healthy groundwater recharge. The region's water supply is projected to be plentiful as long as precipitation remains consistent and growth is moderate.

However, the aquifer is vulnerable to the water-related effects of climate change. Coastal flooding presents a threat to the region's water supply. Water demand is expected to increase. The increased demand is attributed to population growth and urbanization, but increased demand is also likely due to increased summer temperatures. In Oregon, there is a relationship between annual average water consumption and annual average temperature. Research on urban water demand suggests that temperature is the most influential climate variable on water consumption (Oregon Climate Change Research Institute 2012).

7 Tobyhanna Army Depot

Tobyhanna Army Depot (TYAD) is located in Coolbaugh Township, Monroe County, in northeastern Pennsylvania. There has been an Army presence on the site where the current installation is located since 1912. The site initially hosted a field artillery training camp and subsequently a Civilian Conservation Corps (CCC) camp. Other uses include artillery training of West Point cadets, a World War II prisoner-of-war camp, and a storage point for gliders used in the D-Day landings. The installation's activities declined after World War II, but in 1953 the Army Signal Corps established TYAD (Pike 2013).

TYAD (Figure 57) is the military's primary facility for the repair, overhaul, maintenance, integration, fabrication, upgrade, and total life cycle support of communications-electronics equipment and systems, and is also one of the region's largest employers. The Depot is the largest full-service communications and electronics maintenance facility in the DOD (TYAD 2012a). TYAD sits on 1,293 acres of land with 4.1 million sq ft of buildings and storage space (Pike 2013).

Figure 57. Tobyhanna Army Depot, PA.



The installation is situated 25 miles southeast of Scranton and approximately 75 and 85 miles, respectively, from the New York City and Philadelphia metropolitan areas (Figure 58). This area is well known for the natural beauty of the Pocono Mountains and of the nearby state parks, Tobyhanna State Park, and Goldsboro State Park.

7.1 Regional definition

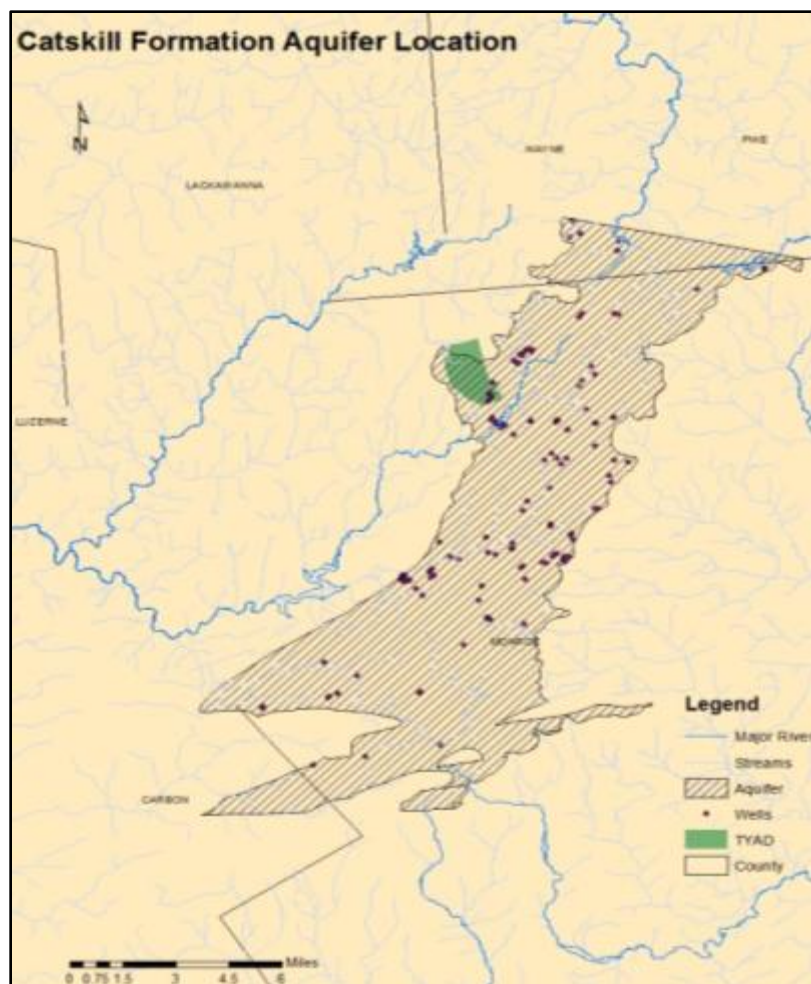
The study region includes a large portion of northwestern Monroe County and small portions of Pike, Wayne, and Carbon counties. The region is defined by the location of the Poplar Gap of the Catskills Formation aquifer system and by the surface water drainage area that consists of the Tobyhanna Creek watershed. The watershed is approximately 129 square miles in size (F. X. Browne, Inc. 2004). The groundwater is confined based on the aquifer characteristics, so a small study region is appropriate (Figure 59).

Figure 58. Tobyhanna Army Depot location map.



Source: www.ship.edu

Figure 59. Aquifer location with county boundaries.



7.1.1 Demographic trends

In recent years, Monroe County has been one of the fastest growing counties in Pennsylvania. This growth is attributed to its proximity to major metropolitan areas and the flourishing tourist industry in the Pocono Mountain region. Between 1990 and 2000, the county population grew by almost 45% due to permanent and seasonal in-migration from both the Philadelphia and New York City metropolitan areas (Monroe County Planning Commission 1999). The region is a desirable place to live because of the relative low-cost of living compared to the metro areas, quality school systems, and rural setting. The region's close proximity to both the metro areas allows for relatively short commuting times (Staff 2013)

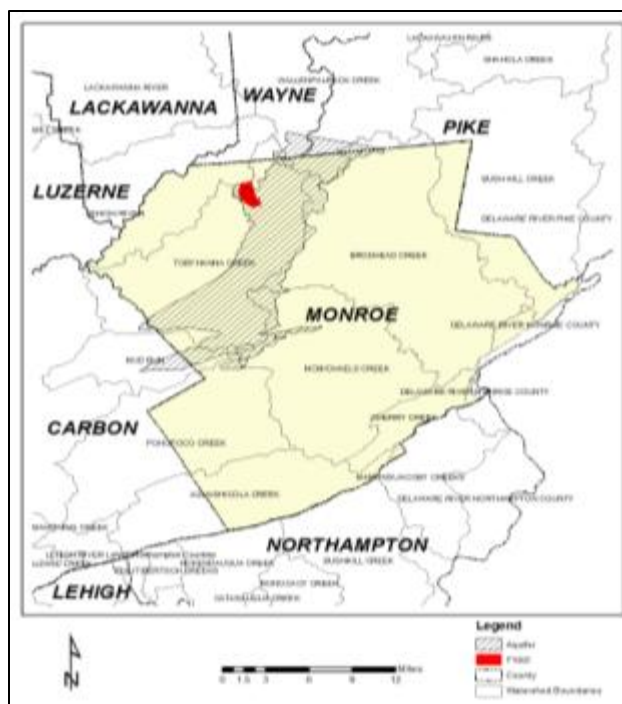
Monroe County's population grew 22.5% between 2000 and 2010 to 169,842 people (US Census Bureau 2010). County population is expected

to continue to grow, but at a slower pace than during previous decades. Based on projections provided by the Monroe County Planning Commission, the population is expected to reach 224,341 by 2020 (Monroe County Planning Commission 2012).

7.1.2 Water sources

Tobyhanna Depot's water supply is withdrawn from a fractured sandstone aquifer known as the Poplar Gap Member of the Catskill Formation (Figure 60). The aquifer is located in a consolidated rock formation, whereby groundwater is found within fractured rocks underneath the land surface (Sloto 2007). Water bearing zones within the aquifer system are based on well depth and the location of geologic formations. Water bearing characteristics for the Catskill Formation include "on the average, one of every four wells located, drilled and developed for high yield will probably produce about 75 gpm or more, with 50 ft of drawdown after 24 hours of pumping." It is estimated that wells in Poplar Gap yield two to seven times better than other members of the Catskills Formation (Carswell 1979). In this area most of the drinking water wells are derived from confined aquifers that are hydrologically disconnected (F. X. Browne, Inc. 2004).

Figure 60. Watershed boundaries in the study region.



7.1.3 Water rights and regulations

Pennsylvania common law defines four water categories including surface water, diffused surface waters, ground water in well-defined subterranean streams, and percolating ground waters. Each category has unique rules governing diversion, use, and disposal.

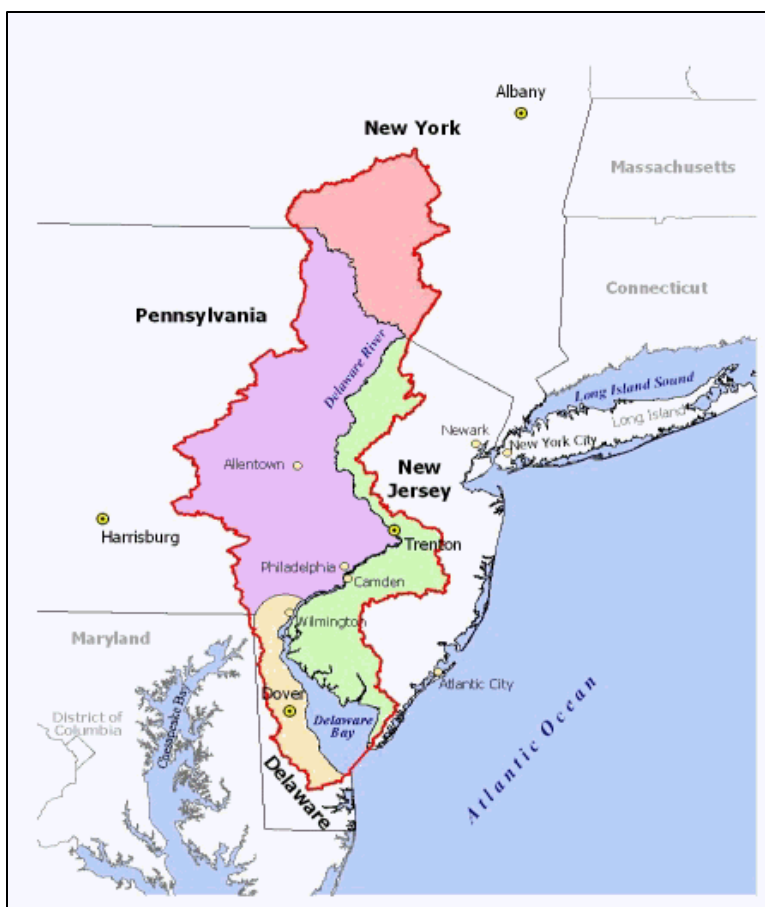
Surface water withdrawals are based on riparian rights, which grant withdrawal rights to waters flowing in a natural watercourse to adjacent landowners whose real property abuts the body of water. Waters may not be diverted to noncontiguous lands located some distance from the watercourse or to contiguous lands that are within a different watershed. The waters must be returned to the original stream (Johnson 2009).

Pennsylvania follows the American Rule for withdrawal of groundwater for percolating groundwater. This allows a landowner to withdraw percolating groundwater for natural and ordinary uses on that land regardless of the effects on neighbors. There is considerable debate regarding this method of allocating and managing water. In the event there is a dispute, “the deepest well and the most powerful pump wins” (Johnson 2009).

TYAD is part of the Delaware River Basin Commission (DRBC, shown in Figure 61) and is subject to the compact legislation between Delaware, New Jersey, Pennsylvania, New York, and the Federal government (DRBC 1961). The Commission is granted authority over allocation of basin water and reviews both surface and groundwater withdrawals. However, the review is limited. Permits are required for all withdrawals of at least 100,000 gpd and for withdrawals of 10,000 gpd located in a Groundwater Protection Area (DRBC 2010).

Pennsylvania’s water system types are subject to unique regulations and different regulatory agency oversight. Public water systems operated by a municipality are regulated by the state Department of Environmental Protection under state regulatory and Federal regulatory programs. Public utilities are authorized and regulated by the Pennsylvania Public Utility Commission subject to the system construction and operation regulations of the Pennsylvania Department of Environmental Protection (PADEP).

Figure 61. Location of DRBC Boundary.



Source: DRBC Public Info/Newsroom

PADEP's Bureau of Water Supplies reviews permits for public water systems using surface water, which account for about 10% of total withdrawals in the state (PHRC 2007). TYAD is not subject to state water permits for water withdrawal due to its groundwater source. The installation is required to comply with the SDWA and obtain a National Pollutant Discharge Elimination System (NPDES) permit for industrial and municipal treatment and stormwater discharge.

Pennsylvania does not have state-level regulations controlling the construction or use of individual private water wells that pump less than an average daily flow of 10,000 gpd over a 30-day period, although some county health departments require permits. Individual well owners are responsible for the quality of their own water. The Water Planning Act (Act 220) requires the PADEP to update the State Water Plan and determine the current and future availability of groundwater. The Act requires any commercial, industrial, agricultural, or individual activity that withdraws

or uses 10,000 or more gallons of water per day, averaged over any 30-day period, to register and periodically report their water use to PADEP. Individual activities that use less than 10,000 gallons per day are required to register on a voluntary basis (PHRC 2007).

7.1.4 Climate

Tobyhanna's average temperature is 44.5 °F. The coldest month is January with the average high of 30 °F and the warmest month is July with average high temperature of 78 °F (US Climate Data 2013). Annual average precipitation is 42 in. TYAD records weather data specific to the installation and the immediate surroundings. These records indicate that annual precipitation is about a 49.75 in., with September the wettest month (TYAD 2012b).

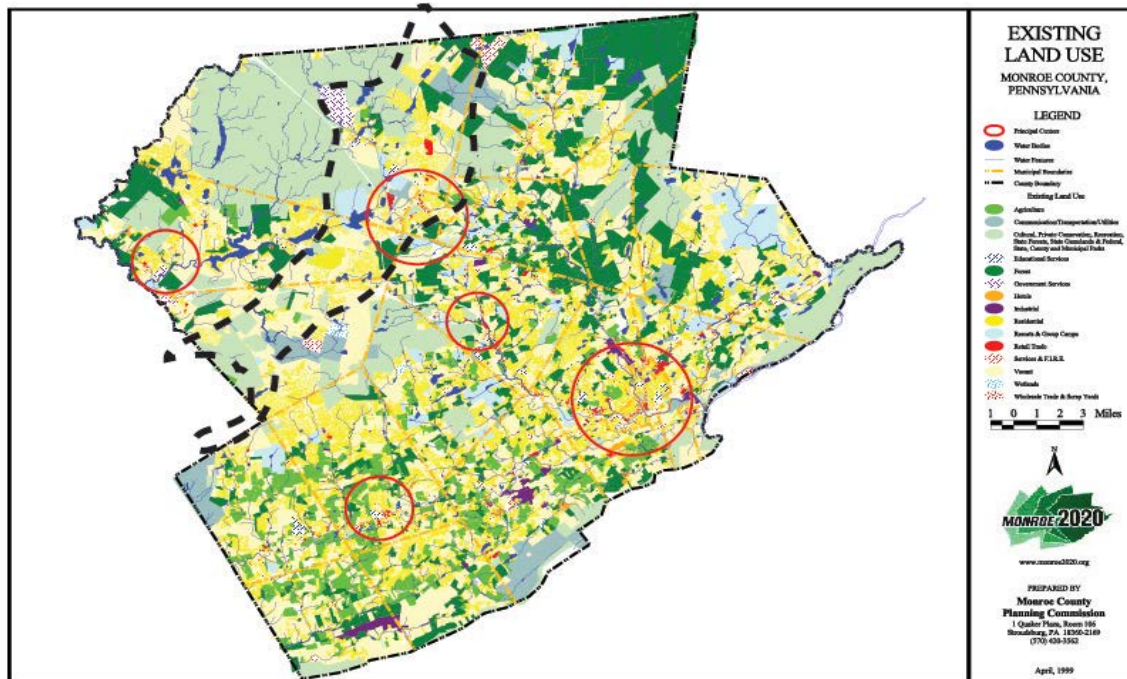
7.1.5 Land use/land cover

Developed land located in the region consists of principal centers, roadway corridors, interstate intersections, and large residential subdivisions (Monroe County Planning Commission 1999). The area surrounding the installation includes significant preserved lands that include the Tobyhanna State Park and large game preserves. The area also consists of the large-lot subdivisions with septic tanks and private water wells. In some cases the residential areas consists of second homes belonging to residents from the metro areas. Figure 62 shows regional land use.

7.1.6 Historic water demand

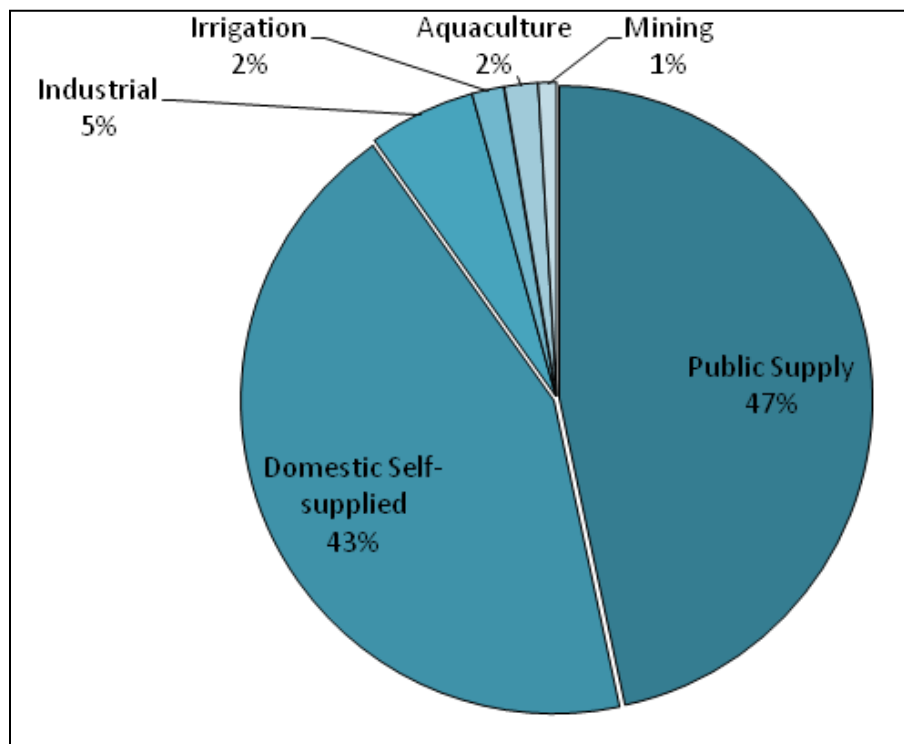
Historic water withdrawals for Monroe County are primarily from surface water, 53.39 mgd, with groundwater withdrawals (Figure 63) of 11.20 mgd (USGS 2005). These estimates of water withdrawals are categorized as public supply, self-supplied domestic, industrial, irrigation, mining, and aquaculture at the county level. Based on county level data, public supply and domestic, self-supplied water use account for a significant amount of the groundwater withdrawals (USGS 2005).

Figure 62. Land Use in Monroe County.



Source: Monroe County Comprehensive Plan, 2012.

Figure 63. Groundwater use by sector in Monroe County, 2005.



Source: USGS 2005

7.2 Developing the Tobyhanna regional model

Tobyhanna Army Depot receives its drinking water from six active wells, producing a total capacity of 912,970 gpd resulting in a total annual capacity of 333 million gallons (TYAD 2012b). The water is treated and pumped to two main water storage tanks and gravity fed through the distribution system. The wells are used every day, if required, to supply water w to TYAD. The water distribution system consists of approximately 85,000 linear feet of water mains, with diameters ranging from 1 to 14 in. in size, as shown in Figure 64 (USACE 2010).

7.2.1 Water supply projections

7.2.1.1 Description

The complexity of aquifers makes it difficult to accurately project the amount of water available for water supply, as groundwater systems are dependent on geology, climate, physiographic, and consumptive patterns. The amount of groundwater supply for this particular area is relatively unknown because of an absence of a detailed aquifer study. Estimates of water supply are based on well yield characteristics obtained from previous studies.

Figure 64. TYAD water distribution system.



Source: TYAD Environmental Office

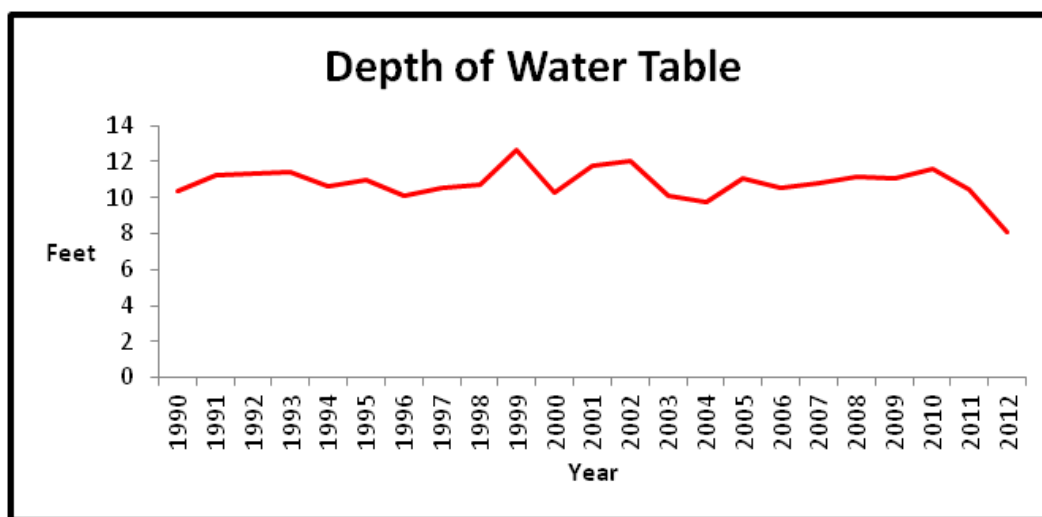
7.2.1.2 Drivers for water supply

Recharge of the aquifer occurs through the hydrologic cycle. The average annual precipitation for the study area is 49 in., of which 27 in. leaves the area through stream flow. It is estimated that 65% of the stream flow travels through the groundwater reservoir. It is estimated that 18 in. of precipitation is lost to evapotranspiration (Carswell 1979).

The level of groundwater fluctuates in response to inputs and outputs of the groundwater system. Recharge occurs through precipitation and stream flow, and discharge through well pumping, evapotranspiration, and stream flow. Groundwater levels are at their highest from November to May when the groundwater and soil moisture evapotranspiration are at a minimum and recharge is at a maximum. Conversely, water levels generally decline from June to October when groundwater and soil moisture evapotranspiration are at a maximum and recharge is at a minimum (Carswell 1979).

Generally, groundwater levels have fluctuated over the 22-year period between 1990 and 2012, but there has been a slight decline since 2009, as shown in Figure 65 (USGS 2012b).

Figure 65. Historic groundwater levels at WELL #MO 190 Monroe County.



Source: USGS Groundwater Watch

7.2.2 Water demand projections

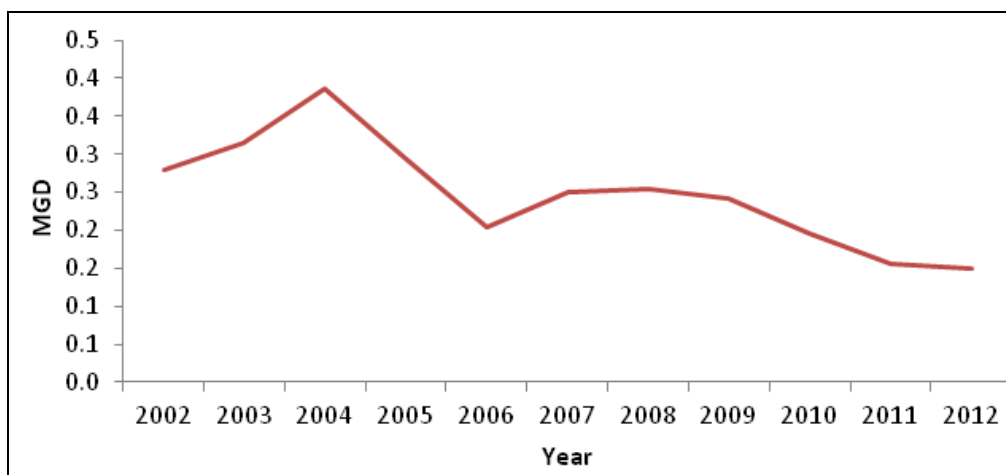
The water demand projections consist of a regional demand analysis based on data specific to the study region and Tobyhanna Army Depot. The baseline is determined by known area consumption data and population projections for the study area. This projection, which assumes that total withdrawals will grow at the same rate as population, estimates demand through 2040. The following section examines the long-term demand for the installation and the region.

7.2.2.1 Tobyhanna Army Depot demand projections

The water demand model uses historic consumption data, real property data, and information from the Tobyhanna Army Depot Net Zero Water Program Balance Report conducted by PNNL. The installation also provided extensive historic water use data, well production, and metering information. Water use at TYAD has declined significantly since 2009 (Figure 66) when the average amount of water use was about 0.27 mgd/day. Considering historic and current water use for the installation, the baseline for water consumption is estimated at 0.20 mgd/day. It is expected that TYAD will achieve the water reduction target established by EO 13514. The EO requires 2% annual reduction in potable water or 26% through FY2020, as compared to base year 2007. Industrial, landscaping, and agricultural water consumption must be reduced by 2% annually or 20% through FY2020, as compared to the 2010 base year.

Table 13 lists the inputs for the demand model that were used to calculate baseline TYAD water use. The model incorporates real property data by using category codes to calculate the total number of buildings, primary and secondary quantities, and square feet. The input labeled *barracks* includes the number of beds available on the installation, and *family housing* includes the number of housing units. *Transient population* includes unit training, visitors, and contractors. *Civilian workforce* includes full-time employees working at TYAD.

Figure 66. Historic water use at TYAD (average MGD from 2002-2012).



Source: TYAD Environmental Records

Table 13. TYAD installation water demand model inputs.

Projection Inputs	Baseline Units
Barracks	36
Family Housing	133
Transient Population	400
Dependents	0
Civilian Workforce	5,200
Deployment Factor: Family Housing	1.00
Deployment Factor: Barracks	0.80
Industrial/Maintenance Factor	1.00
Storage Growth Factor	1.00
High Water Use Facilities Factor	1.00
Irrigated Land Factor	1.00
Losses Factor	1.00
Moisture Deficit Factor (in)	18

Deployment factor represents the average occupancy level for the barracks. Based on occupancy information provided in the water balance report (PNNL 2012), the deployment factor for the barracks is 0.80, which means that 80% of the barracks is occupied over a year. For family housing, the deployment factor is 1.00, which considers year-round occupancy of the housing. Other factors such as industrial/maintenance, storage growth, high water use facilities, irrigated land, and losses are set to 1.00, which maintains the current level of intensity. The moisture deficit factor is the local evapotranspiration rate, which is 18 in. of surface water lost each year.

The model uses estimated consumption in gallons per unit per day by the type of facility located on TYAD. The unit varies, as in some instances (barracks, administration, lodging, commercial) the unit is per capita. For industrial/maintenance and storage, the unit is the building. Per-capita use is estimated (PNNL 2012).

7.2.2.2 Regional water demand projections

The water demand projection for the region and the installation uses 2005 US Geological Survey (USGS) water use data for Monroe County. The estimates are based on groundwater withdrawals, but not surface water, because groundwater is the installation's sole water source. The model includes non-TYAD entities that also draw on the same groundwater. The model considers population projections for the selected area. Estimates are for the study area weighted by the percentage of the county population living in the region. Population data is derived from 2010 US Census Tract information.

The baseline demand for all of Monroe County is estimated at 11.58 mgd, and at 1.7 mgd for the study region (Figure 67). Private well owners and community water suppliers use this water for irrigation, agriculture, aquaculture, and domestic purposes. Projections of future water demand for Monroe County rise to 19.1 mgd in 2040. Water use for the study region is projected to climb to 2.72 mgd by 2040 (Table 14). These estimates are extrapolated based on moderate population growth for the county and known consumption data.

There are approximately 80 community suppliers located within the county. The largest is the Stroudsburg Municipal Authority, with approximately 5,400 connections and consumption of 1.8 mgd. The smallest is Pocono Valley Health Center, serving 15 people at 600 gpd (Monroe County Planning Commission 1999). A community water system is defined as a public water system that serves at least 15 service connections used by year-round residents or that regularly serves at least 25 year-round residents. These systems are designed and permitted in accordance with Pennsylvania's Department of Environmental Protection (25 PA Code, Chapter 109). In the case where no public water is accessible, water is furnished by private wells, which are currently unregulated in Pennsylvania (PHRC 2007). There are no requirements for well construction materials, yield, or quality.

Figure 67. Baseline water use by location.

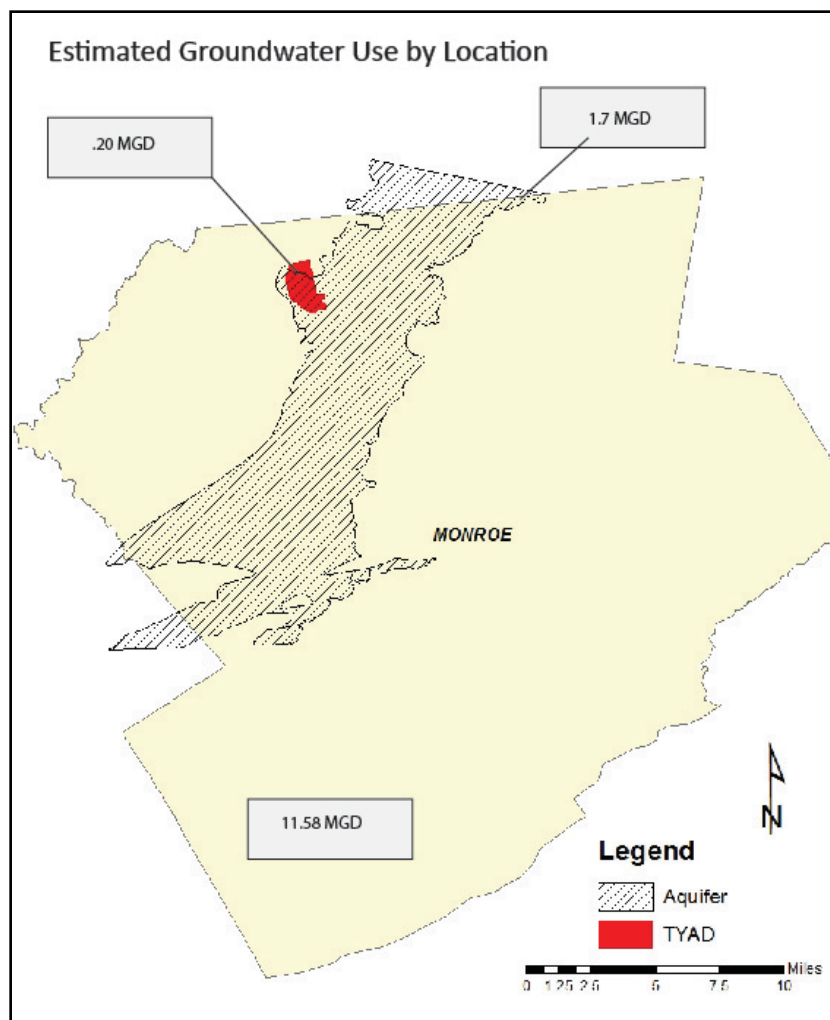


Table 14. Projected water demand for the TYAD study region.

	2010	2015	2020	2025	2030	2035	2040
Study Area (MGD)	1.70	1.83	1.96	2.15	2.26	2.37	2.72
Monroe County (MGD)	11.58	12.01	13.20	14.63	15.92	17.54	19.12

7.2.3 Water availability scenarios

7.2.3.1 Scenario 1 – Status Quo

Scenario 1 assumes existing rates of water consumption, precipitation, and population change will remain steady. It also assumes that aquifer recharge will remain constant and that there will be a slight increase in groundwater users in the region. Climate change is assumed to have minimal effect on water resources. Compared with current conditions, there is a slight in-

crease in precipitation and evapotranspiration. Additionally, TYAD is expected to reduce water use by 2% annually. Based on these conditions in the status quo scenario, recharge is likely to be reduced by 0.52 in.

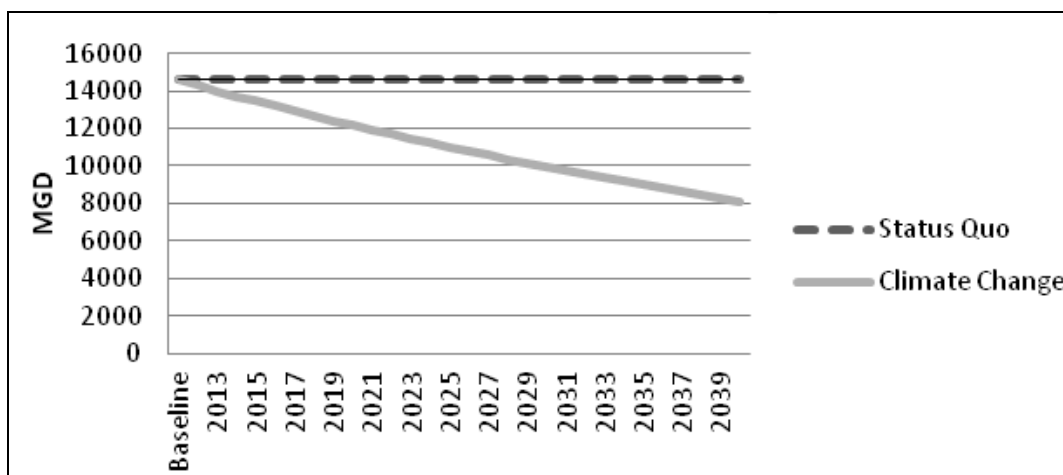
7.2.3.2 Scenario 2 – Climate Change

This scenario incorporates the projected effects of climate change on both water supply and demand. Pennsylvania's climate has already begun to change as winters are 4 degrees Fahrenheit warmer in 2008 than they were in 1970. Temperatures are expected to continue to increase evenly throughout the year. These increases are likely to lead to increasing evapotranspiration that will have significant effects on aquifer recharge. Precipitation is projected to increase during the winter months and to occur as rain rather than snow. This will increase the likelihood of heavy precipitation events and flooding (Union of Concerned Scientists 2008).

If precipitation and evapotranspiration are about equal, it is likely that soil moisture will decrease throughout late spring and early fall. There is a possibility that groundwater recharge could increase due to fewer days with frozen ground and more precipitation during winter time when evaporation is low and plants are not active. Accordingly, there is a possibility that small increases in runoff in the range of 5 to 10% could occur (Union of Concerned Scientists 2008). Increased demand can be expected based on the potential climate change effects of coastal flooding in New York City and Philadelphia and the movement of people to interior locations closer to TYAD.

Scenario 2 assumes a 2% aquifer loss each year based on drier summers. Although climate change projections include a higher concentration of rainfall during the winter months, the model assumes a loss in aquifer recharge due to extreme dry conditions during the summer. Based on the characteristics of the aquifer, there are limitations to its storage capacity, thus reducing the availability of water during periods with the highest demand. Temperature increases are likely to increase the evaporation rate while increases in impervious surfaces will affect runoff. These conditions combine for a net loss in aquifer recharge of 4.85 in. annually (Figure 68).

Figure 68. Estimated water supply loss due to climate change.



7.2.3.3 Scenario 3 – Regional Growth

Scenario 3 assumes the continuation of the recent trend in regional population growth. There has been significant growth in the past 20 years, but recent growth within the region has slowed. This scenario assumes that demand will increase, but at a slower rate than in previous years. In this scenario, the change in regional population is projected to increase by 8% between the years of 2010 and 2040 (Figure 69). The limited growth is due to the presence of preserved/undevelopable land (state parks and game lands) located within the aquifer.

This scenario also assumes a greater demand for water based on changes in the tourist industry. Currently, the area contains several ski resorts that operate during the winter season. The resorts use natural snow, but have been increasingly producing manmade snow to meet the demand for tourist activities. Additionally, these resorts are adding large indoor water parks to their business model (Staff 2013). These new recreational facilities will require significant annual amounts of water to operate. The increased amount of urban development will increase impervious areas. This will affect the amount of runoff, which will then reduce the water available to recharge the aquifer. This scenario projects loss in aquifer recharge of 2.7 in. per year, which will reduce the available groundwater supply (see Figure 70).

Figure 69. Population projections due to regional growth

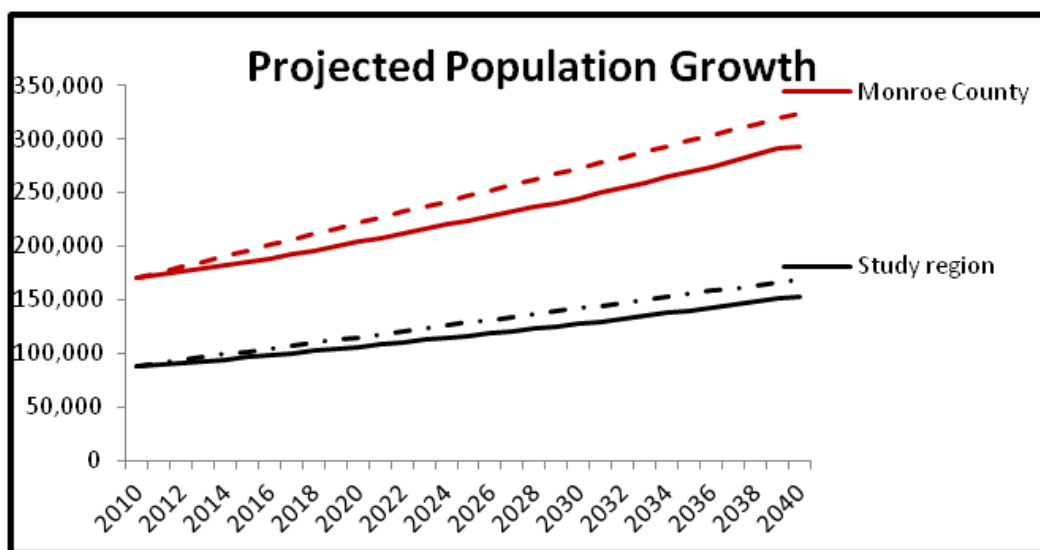
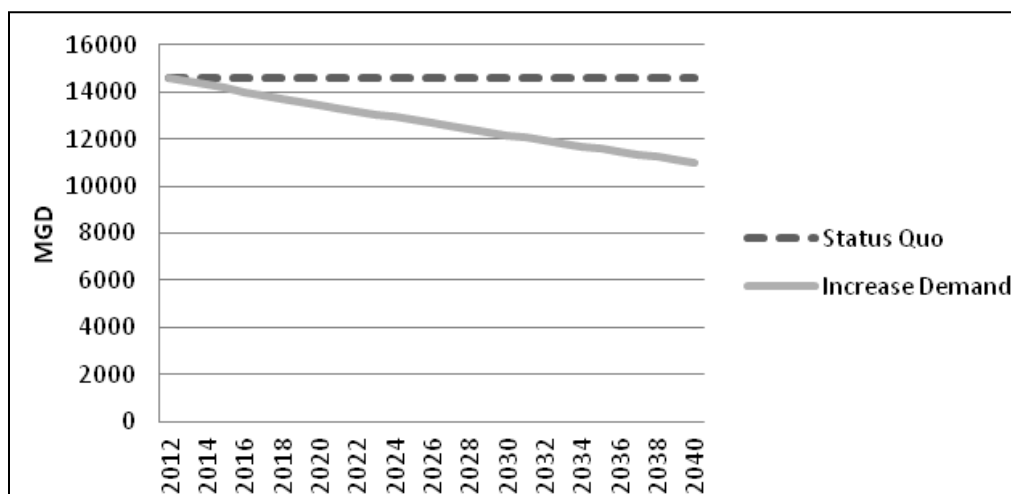


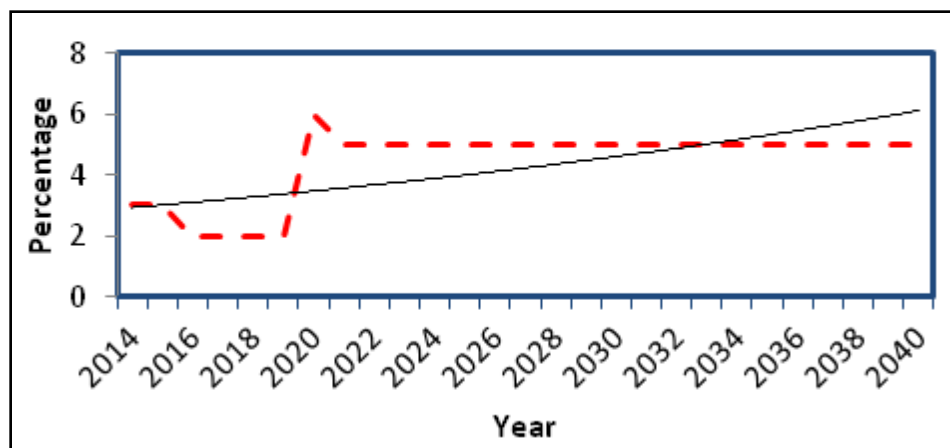
Figure 70. Water supply loss due to regional growth.



7.2.3.4 Scenario 5 – Water Efficiency

This scenario assumes that water conservation and efficiency programs have an effect on water consumption within the study region. It considers water efficiency and conservation for both the installation and region. To-byhanna Army Depot has already begun an extensive leak detection program as part of their conservation efforts. TYAD has a more aggressive plan to reduce water use beyond the mandated goal of 2% annually by 2020. If the installation implements the program, an average water reduction of 5% annually would occur (Figure 71) (Wildoner 2012).

Figure 71. Potential Water Reduction at TYAD.



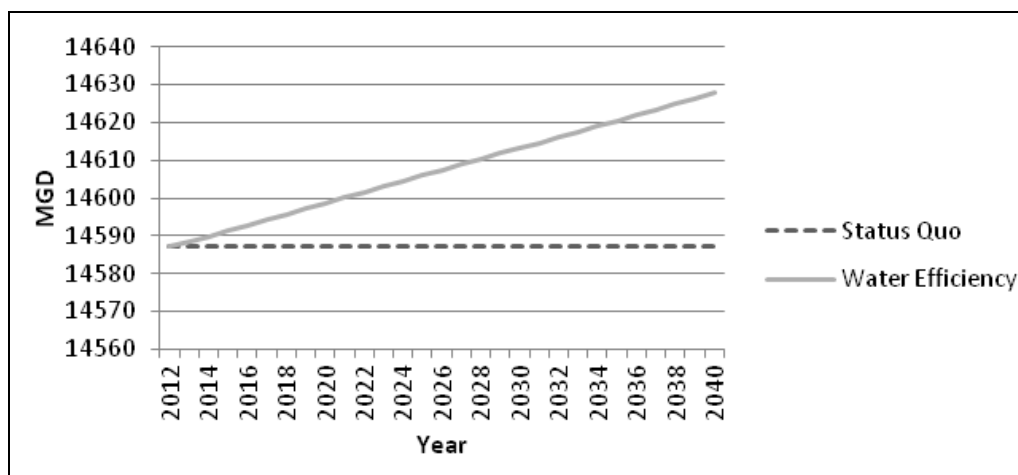
Source: TYAD

At present, neither Pennsylvania nor the region has initiatives to conserve individual household water consumption. Policies and education programs would need to be established to benefit from water efficiency programs (AWE and ELI 2012). Significant reductions in the use of private wells, public education, and residential rebates are required for this scenario to be effective. In addition, the community water suppliers would need to establish leak detection programs to evaluate distribution systems and promote conservation measures, such as new water efficient fixtures and rain barrels, to their customers. If these programs were regional, the scenario projects a possible gain in aquifer storage of 0.94 in. per year. Figure 72 shows the results of this scenario.

7.2.3.5 Scenario results

The water supply model calculates estimated aquifer recharge based on varying conditions because the absolute amount of groundwater available in the Catskills Formation aquifer region is unknown. The aquifer's water supply fluctuates under different scenarios (Table 15). All of the scenarios except *Water Efficiency* result in a net loss in aquifer recharge. Based on the scenario results, groundwater availability is expected to decrease by 2040. Even in the *Status Quo* scenario, which takes into consideration moderate growth and climatic shifts, there is a slight reduction in aquifer recharge. The *Climate Change* scenario has the greatest effect on aquifer recharge.

Figure 72. Regional water supply with water efficiency.



If these recharge losses were to occur concurrently with significant population growth within the study area, there is a possibility of significant aquifer depletion. Increased growth has the potential to increase water with an accompanying increase in the creation of impervious surfaces exacerbating the effects. The rate of rainfall will determine how much runoff finds its way into the aquifer system as increased heavy downpours will produce substantial surface runoff.

Table 15. Roll-up of scenario results.

	Baseline	Scenario 1- Status Quo	Scenario 3- Climate Change (Dry)	Scenario 4- Increased Population	Scenario 5- Water Conservation
Aquifer Recharge	19	18.48	14.15	16.24	19.94
Withdrawals TYAD	0.2	0.196	0.196	0.196	0.196
Region	1.7	2.72	2.72	2.86	2.1
Yearly Gain Aquifer Supply		-0.52	-4.85	-2.7	0.94

7.3 Water sustainability assessment for Tobyhanna Army Depot

The complexity and variability of aquifer systems in the Tobyhanna Army Depot study region, along with the lack of groundwater studies, contribute to the difficulty of determining the absolute amount of groundwater available for regional water supply. This uncertainty is exacerbated by an absence of documentation for private well withdrawals, which can be substantial. It is estimated that half of Pennsylvania's population receives their water supply from groundwater wells and springs. These wells can be drilled almost anywhere and are relatively unregulated (USGS 2005).

The assessment refers to two older studies of the Poplar Gap of the Catskills Formation. However, there are limitations to the available data. Sloto and Buxton (2007) use a model to estimate recharge of the groundwater, but do not provide recharge zones. They rely on lithological and physiographic province to locate the source of groundwater. Aquifer characteristics of well yield are presented (Sloto 2007), but do not describe the amount of groundwater available or the location of the aquifer. Again, the study relies on the underlying rock formation to locate groundwater resources.

Water availability to TYAD and the region will depend on changes in water demand, the effects of climate change on the hydrologic cycle, and the effectiveness of region-wide water conservation efforts. Based on known characteristics of the aquifer, groundwater is replenished regularly by the natural hydrological cycle. Groundwater sources are vulnerable if the hydrological cycle is disrupted or shifted by climate change. The aquifer is already at risk due to short-term water shortages during the dry summer months. If the projected extreme climate change occurs, the flood-drought cycle could significantly reduce the amount of groundwater available for the installation and the region.

Pennsylvania has groundwater quality protection initiatives, but it does not have statewide conservation programs. It is difficult to implement a region-wide groundwater resource plan because of the abundance of individual private wells within the region and the lack of regulation on the use of these wells. It is critical to institute public policy that evaluates the amount of groundwater being withdrawn from the aquifer to ensure long-term aquifer sustainability. It is also important to implement water conservation strategies that include public education and outreach.

8 Conclusion

Threats to water sustainability at Army installations are accelerating in frequency and reach. Many of the conditions that affect water supply and demand for installations are regional in nature. This report has documented the regional approach and findings for water sustainability assessments of four Net-Zero Water installations:

- Aberdeen Proving Ground, MD
- Fort Buchanan, PR
- Camp Rilea, OR
- Tobyhanna Army Depot, PA.*

In addition, this work explored draft metrics to support requirements of the 2012 Army Campaign Plan major objective 8-3, “Improve Water Security and Sustainability across Army Installations and Forward Operations.”

8.1 Installation findings

8.1.1 Aberdeen Proving Ground

The water agreements between the City of Aberdeen with Havre de Grace, Harford County, Baltimore County, and other entities are extremely complex and will only increase in complexity in the future. The dependence on neighboring cities, counties, and states is a vulnerability to the City of Aberdeen and APG. APG must put greater emphasis on becoming self-reliant when it comes to water resources. To do that, two major adjustments must be made: (1) switch to groundwater located at the installation and (2) increase water conservation efforts. The water use category that offers the greatest reduction potential for the installation is laboratory use, but it is also riddled with obstacles. Overcoming this hurdle may require major recalibration of upcoming contracts as well as those made decades ago.

APG’s path to sustainability requires a combination of several policies and measures as well as steps to simplify the installation’s relationships with

* The four other net zero water installation water sustainability assessments were documented in an earlier technical report, ERDC/CERL TR-11-5, March 2011.

water supply sources and to more clearly break down how water is being used on the installation. A few of many challenges that must be overcome to achieve sustainability include reviews of: contracts that go back decades, installation-tenant relationships, and the cost of maintaining a water treatment plants. Those hurdles, although difficult, should prove to be easier than having to maneuver among agreements between the cities, counties, and states beyond APG.

8.1.2 Fort Buchanan

Fort Buchanan's water supply and associated infrastructure is dependent on PRASA because of its extensive control over the island's water resources. The installation has several options to help minimize its dependency on outside water resources. Fixing the existing leaking water distribution is the first option because it would greatly raise the efficiency of the system. The second option involves pumping groundwater. Treating water to make it drinkable can be a costly task. Fort Buchanan plans to draw groundwater for golf course irrigation. The third option would take advantage of the high precipitation rate at Fort Buchanan to subtract roughly 40 kgal from their water bill.

Fort Buchanan will unlikely be able break its reliance on PRASA-supplied water any time soon. Fostering greater collaborative efforts with PRASA is therefore in Fort Buchanan's best interest. Such efforts may include teaming up to create dredging schedules, to provide technical expertise, and to promote leak deterrent methods to fortify the water distribution system of the region. Strengthening the collective efforts between PRASA and the installation will not only help the long-term sustainability of the region, it will minimize the vulnerabilities of Fort Buchanan.

8.1.3 Camp Rilea

Continued water availability in the Camp Rilea study region will depend on increased demand, climate change, and the effectiveness of region-wide conservation efforts. Based on known characteristics of the aquifer, groundwater is replenished regularly by the natural hydrological cycle. The abundance of rainfall and quick absorption of the shallow, dunal aquifer currently maintains healthy groundwater recharge. The region's water supply is projected to be plentiful as long as precipitation remains consistent and growth is moderate.

However, the aquifer is vulnerable to the water-related effects of climate change. Coastal flooding presents a threat to the region's water supply. Water demand is expected to increase. Although increased demand is attributed to population growth and urbanization, it is also likely due to increased summer temperatures. In Oregon, there is a relationship between annual average water consumption and annual average temperature. Research on urban water demand suggests that temperature is the most influential climate variable on water consumption.

8.1.4 Tobyhanna Army Depot

Water availability to TYAD and the region will depend on changes in water demand, the effects of climate change on the hydrologic cycle, and the effectiveness of region-wide water conservation efforts. Based on known characteristics of the aquifer, groundwater is replenished regularly by the natural hydrological cycle. Groundwater sources are vulnerable if the hydrological cycle is disrupted or shifted by climate change. The aquifer is already at risk due to short-term water shortages during the dry summer months. If the projected extreme climate change occurs, the flood-drought cycle could significantly reduce the amount of groundwater available for the installation and the region.

The complexity and variability of aquifer systems in the Tobyhanna Army Depot study region, along with the lack of groundwater studies, contribute to the difficulty of determining the absolute amount of groundwater available for regional water supply. This uncertainty is exacerbated by an absence of documentation for private well withdrawals, which can be substantial. It is estimated that half of Pennsylvania's population receives their water supply from groundwater wells and springs. These wells can be drilled almost anywhere and are relatively unregulated.

Pennsylvania has groundwater quality protection initiatives, but it does not have statewide conservation programs. It is difficult to implement a region-wide groundwater resource plan because of the abundance of individual private wells within the region and the lack of regulation on the use of these wells. It is critical to institute public policy that evaluates the amount of groundwater being withdrawn from the aquifer to ensure long-term aquifer sustainability. It is also important to implement water conservation strategies that include public education and outreach.

8.2 Proposed water metrics

8.2.1 Potable water distribution system linear feet assessed for leaks (candidate metric 8-3.1.1)

Developing a candidate metric for leak detection requires knowledge of the age and condition of Army drinking water infrastructure to optimize leak detection resources by focusing on systems which can be repaired if leaks are discovered.

The following recommendations are made:

- Identify the recapitalization requirement for installation water distribution systems. Use BUILDER™ and ISR-I to prioritize both leak detection surveys and water infrastructure upgrades.
- Identify GIS systems currently in use on installations.
- Assess the ability of Army Mapper to support the data requirements of this metric. Identify the required data layers and the reporting status/accuracy across installations.
- Include a leak detection requirement in the Annual Work Plan (see DA Pam 420-06 [HQDA 1997]).
- Add additional AEWRS reporting fields (similar to Energy Manager Data Entry of BMPs, Water Management Plan, Energy Personnel, ESPC contracts, UESC projects, ECIP projects).

Appendix B to this report contains draft operational definitions.

8.2.2 Gallons per person per day (candidate metric 8-3.2.2)

A combination of efforts will be required to capture a daily per capita metric at a shorter frequency than possible by using existing quarterly data.

The following recommendations are made:

- Strategically install meters for barracks groups, housing, AAFES, MWR, irrigation, and other high use facilities and activities.
- Require all meters to send data to the MDMS at each installation.
- Request DPW energy and water managers with access to MDMS to reconcile population data using ASIP, DEERS, on-base housing, and high use buildings and input this data into AEWRS.

Appendix B to this report contains draft operational definitions.

Acronyms and Abbreviations

Abbreviation	Full Term
AAFES	Army and Air Force Exchange Service
ACP	Army Campaign Plan
ACSIM	Assistant Chief of Staff for Installation Management
AESIS	Army Energy Security Implementation Strategy
AEWRS	Army Energy and Water Reporting System
AFCEA	Air Force Civil Engineer Support Agency
AIRR	Adjusted Internal Rate of Return
ANSI	American National Standards Institute
APG	Aberdeen Proving Ground
APG-AA	Aberdeen Proving Ground–Aberdeen Area
APG-EA	Aberdeen Proving Ground–Edgewood Area
AR	Army Regulation
ASA(IE&E)	Assistant Secretary of the Army for Installations, Energy and Environment
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASIP	Army Stationing and Installation Plan
ATSDR	Agency for Toxic Substances and Disease Registry
AWE	Alliance for Water Efficiency
AWWA	American Water Works Association
BLCC	Building Life Cycle Cost
BMP	Best Management Practice
BRAC	Base Realignment and Closure
CAC	Common Access Card
CADD	Computer-Aided Drafting and Design
CAP	City of Aberdeen Production
CATCD	Category Code
CCC	Civilian Conservation Corps
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CFR	Code of the Federal Regulations
CFS	Cubic Feet per Second
CIP	Common Installation Picture
CONUS	Continental United States
CSSC	Chesapeake Science and Security Corridor
DA	Department of the Army
DAIM	Department of the Army's Assistant Chief of Staff for Installation Management
DASA	Deputy Assistant Secretary of the Army
DC	District of Columbia

Abbreviation	Full Term
DEERS	Defense Enrollment Eligibility Reporting System
DFMWR	Directorate of Family Morale Welfare & Recreation
DHR	Directorate of Human Resources
DMDC	Defense Manpower Data Center
DNR	Department of Natural Resources
DoD	Department of Defense
USDOE	US Department of Energy
DPW	Directorate of Public Works
DRBC	Delaware River Basin Commission
ECIP	Energy Conservation Investment Program
EISA	US Energy Independence and Security Act of 2007
ELI	Environmental Law Institute
EO	Executive Order
ERDC	Engineer Research and Development Center
ESPC	Energy Savings Performance Contract
ESRI	Environmental Systems Research Institute
FAC	Facility Analysis Category
FCG	Facility Category Group
FEMP	Federal Energy Management Program
FY	Fiscal Year
GAO	Government Accountability Office
GBCI	Green Building Certification Institute
GFEBs	General Fund Enterprise Business System
GIS	Geographic Information System
GLAC	General Ledger Account
GPR	Ground Penetrating Radar
HDPE	High-Density Polyethylene
HQDA	Headquarters, Department of the Army
HQIS	Headquarters Installation Information System
HQUSACE	Headquarters, US Army Corps of Engineers
IAW	In Accordance with
ICC	International Code Council
IES	Illuminating Engineering Society
IFS	Integrated Facilities System
IGI&S	Installation Geospatial Information and Services
IMARC	Installation Management Application Resource Center
IMCOM	US Army Installation Management Command
IPC	International Plumbing Code
IPCC	Intergovernmental Panel on Climate Change
ISR	Installation Status Report
ITTP	Installation Technology Transition Program
JBLM	Joint Base Lewis-McChord

Abbreviation	Full Term
LCC	Life Cycle Cost
LEED	Leadership in Energy and Environmental Design
MCA	Military Construction, Army
MDC	Metropolitan Detention Center
MDE	Maryland Department of the Environment
MEDCOM	Medical Command
MG	million gallons
MGAL	millions of gallons
MGD	million gal/day
MIPR	Military Interdepartmental Purchase Request
MPO	Metropolitan Planning Organization
MTOE	Modification Table of Organization and Equipment
MWR	Morale, Welfare, and Recreation
N/A	Not Applicable
NAVFAC	Naval Facilities Engineering Command
NGB	National Guard Bureau
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRMRL	National Risk Management Research Laboratory
NSN	National Supply Number
NZE	Net Zero Energy
NZI	Net Zero Installation
NZW	Net Zero Water
OACSIM	Office of the Assistant Chief of Staff for Installation Management
OCONUS	Outside Continental United States
OEI	Office of Economic Adjustment
OMB	Office of Management and Budget
ORD	Office of Research and Development
OSD	Office of the Secretary of Defense
PADEP	Pennsylvania Department of Environmental Protection
PAIO	Plans, Analysis, and Integration Office
PEO	Program Executive Officer
PHRC	Pennsylvania Housing Research/Resource Center
PNNL	Pacific Northwest National Laboratory
PR	Puerto Rico
PRASA	Pennsylvania Housing Research/Resource Center
PRIDE	Planning Resource Infrastructure Development and Evaluation
PVC	Polyvinyl Chloride
PX	Post Exchange
QAP	Quality Assurance Plan
REMIS	Real Estate Management Information System

Abbreviation	Full Term
RFMIS	Rental Facilities Management Information System
RPLANS	Real Property Planning and Analysis System
RV	Recreational Vehicle
SAR	Same As Report
SCWTP	Sergio Cuevas Water Treatment Plant
SDSFIE	Spatial Data Standards for Facilities, Infrastructure, and Environment
SDWA	Safe Drinking Water Act
SF	Standard Form
SIR	Savings-to-Investment Ratio
SMS	Sustainment Management System
SRBC	Susquehanna River Basin Commission
SRF	State Revolving Loan Fund
SRM	Sustainment, Restoration, and Modernization
TDA	Tables of Distribution and Allowances
TR	Technical Report
TYAD	Tobyhanna Army Depot
UCONN	University of Connecticut
UESC	Utility Energy Service Contract
UFC	Unified Facilities Criteria
UP	Utilities Privatization
URL	Universal Resource Locator
US	United States
USA	United States of America
USACE	US Army Corps of Engineers
USAG	US Army Garrison
USAWES	US Army Waterways Experiment Station
USBLS	US Bureau of Labor Statistics
USDOE	US Department of Energy
USDOL	US Department of Labor
USEPA	US Environmental Protection Agency
USGAO	US General Accounting Office
USGBC	US Green Building Council
USGS	US Geological Survey
WIFIA	Water Infrastructure Finance Innovations Authority
WWW	World Wide Web

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Appendix A: 2012 Army Campaign Plan

Figure A1. ACP, outcomes, requirements, and campaign objectives.

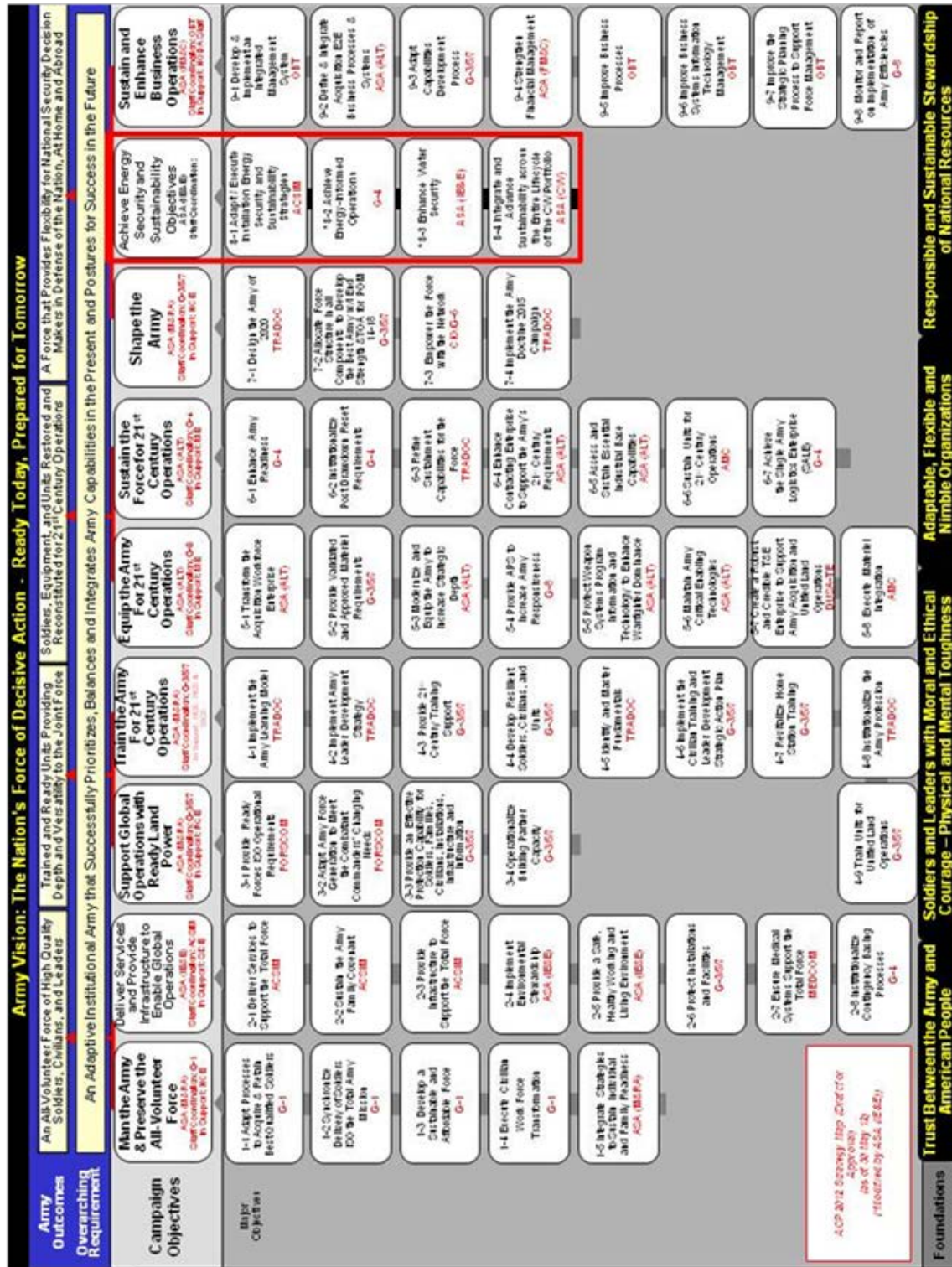


Figure A2. Major Objective 8-3: Enhance Water Security.

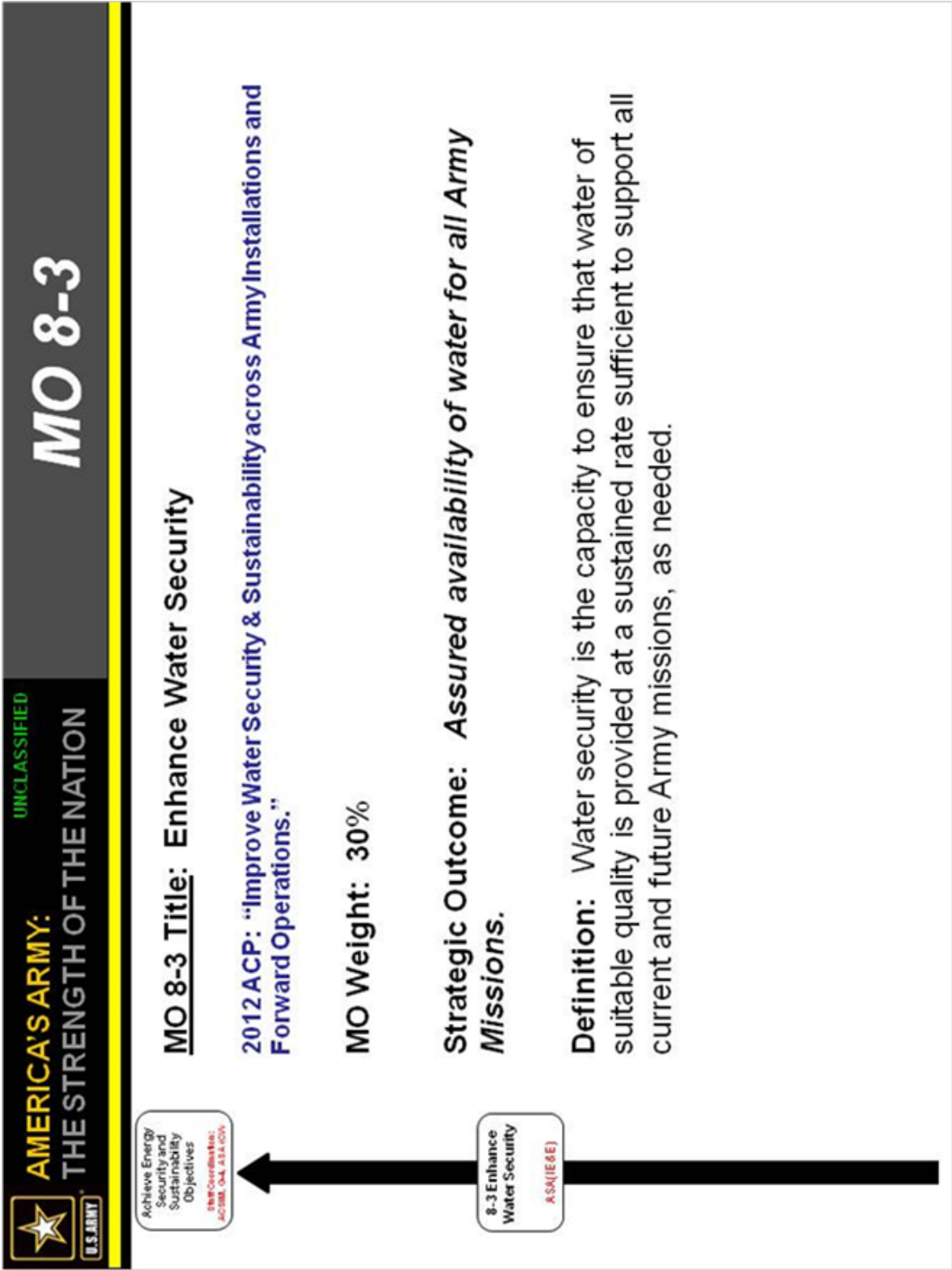


Figure A3. Candidate metrics under Major Objective 8-3.

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MO 8-3 Metrics

Subtasks	Candidate Metrics	Weighting	Frequency of Measurement	Criteria	Value	Trend
8-3.1 Expand Use of Technology to Increase Water Efficiency ²	8-3.1.1 % Potable Water Distribution System Linear Feet Assessed for Leaks	25%	Quarterly	TBD	TBD	
	8-3.1.2 % of Covered Facility Square Footage that completed Water Evaluations			≥ 25% = Green 18%–24% = Amber < 18% = Red		
	8-3.1.3 % of Total Water Meters Installed on Appropriate Facilities and Reporting to MDMS vs. total scheduled			≥ 95% = Green 70%–94% = Amber < 70% = Red		
8-3.2 Reduce Direct Consumptive and Withdrawal Use ²	8-3.2.1 % Reduction in Potable Water Intensity, Measured in Gallons per Gross Square Foot (GAL/GSF)	25%	Quarterly	≥ 8% = Green 6%–7.9% = Amber < 6% = Red		
	8-3.2.2 Gallons per Person per Day			TBD	TBD	
8-3.3 Increase Use of Alternative Water Sources	8-3.3.1 % Reduction in Irrigation, Landscaping, and Agricultural Water Consumption	25%	Quarterly	TBD	TBD	
8-3.4 Reduce Water Consumption on Contingency Basing	8-3.4.1 % of Shower Water Reuse Systems Fielded	25%	Quarterly	TBD	TBD	
8-3.5 Reduce Indirect Consumptive and Withdrawal Use in the Supply Chain	8-3.5.1 % Reduction in Potable water Consumption (Supply Chain)	0	Quarterly	TBD	TBD	

NOTE: PERFORMANCE MEASUREMENTS ARE BASED ON :
² EXECUTIVE ORDER (EO) 13423 and/or EO 13514

TBD = NEW AND/OR UNDER DEVELOPMENT

Appendix B: Metric Operational Definitions

Figure B1. Operational Definition for the candidate metric 8-3.1.1.


Operational Definition			
Measure Number: 8-3.1.1		Owner: DASA(E&S)	
Major Objective: Reduce potable water consumption intensity at permanent installations (8.1)		Army Campaign Plan Objective: Achieve Energy Security and Sustainability Objectives (8.0)	
Description: Potable water distribution system linear feet assessed for leaks			
Lag/Lead: Lag	Frequency: Quarterly	Unit Type: percent	Preferred Trend: Down
Formula: Total amount of linear feet of potable water distribution system assessed for leaks in a quarter / the total linear feet			
Data Sources: Total linear feet of potable water distribution system is available through the ACSIM Headquarters Installation Information System (HQIIS) available at https://www.acsim-apps.army.mil/secure/hqiis/ . Another potential source is GIS data layer for potable water, available through the Army Mapper system. The linear feet of potable water distribution system surveyed for leaks each year is also available from the installation Directorate of Public Works (DPW).			
Data Quality: Variable; UP contractors not required to provide GIS data.		Data Collector: Automated: HQIIS/Army Mapper	
Baseline: None.		Target: Fiscal year 2013: xx% Target by calendar quarter: 2013 1stQ xx%; 2ndQxx%; 3rdQxx%; 4thQxx	
Target Rational: A leak detection measure is needed to support infrastructure water efficiency. Consistent surveys are in line with a regular program of investment in infrastructure recapitalization.		Strategies:	Cost:
		I	TBD
		Total Cost for Strategies	TBD
Accuracy: HQIIS draws data from GFEBS. Army Mapper data are updated quarterly by installation staff.			
Validity: Using percent of potable water line inspected directly addresses water loss.			
Reliability: A leak detection survey will be accurate at a point in time after which new leaks can occur.			
Relevance: The measure draws on data sources which may not be consistent across the Army e.g. UP contractors and NGB.			

Figure B2. Operational definition for the candidate metric 8-3.1.2.

Operational Definition			
Measure Number: 8.3.1.2			Owner: DASA(E&S)
Major Objective: Calculate quarterly per capita water demand			Army Campaign Plan Objective: Achieve Energy Security and Sustainability Objectives (8.0)
Description: Daily estimate of water demand based on potential users on installation			
Lag/Lead: Lag	Frequency: Quarterly	Unit Type: Percent	Preferred Trend: Down
Formula: Average daily water demand/[DEERS pop – ASIP]*1/6 + normal nightly occ + normal daily visitors (ASIP – hsg) * 5/12			
Data Sources: Assigned military and civilian personnel population numbers are available from the ASIP system. Population served data is available from the annual DEERS report. Water demand is available quarterly from AEWRs or monthly from the DPW. Average daily numbers are available from the DPW housing office to include barracks, billeting, transient housing, and post housing. The 1/6 multiplier is based on assuming daily visitors are on post only 4 hours. The 5/12 multiplier is based on a normal business day length of 10 hours.			
Data Quality: Variable		Data Collector: Energy and Water Manager	
		Target: Fiscal year 2013: xx% Target by calendar quarter: 2013 1stQ xx%; 2ndQxxx%; 3rdQxx%; 4thQxx	
Baseline: None.			
Target Rational: A per capita measure offers an alternative measure of water use from building area. Large deployments, both outgoing and incoming, will spike water use intensity when only building area is used. In addition, some large water use activities are more closely associated with population than a building's footprint. Using quarterly data will lag significantly, but should show how deployments affect per capita demand.		Strategies:	Cost:
		Include water per capita metric in quarterly ISR reports.	TBD
		Require input of installation-specific population data into AEWRs.	TBD
		Total Cost for Strategies	TBD
Accuracy: TBD			
Validity: Using gallons per person per day directly addresses potable water consumption.			
Reliability: The population at an installation can vary by an unknown amount on an unknown frequency. The focus might be put on estimating the permanent population vs. the transitory population. It should be reliable for remote installations. For adjacent installations it will be difficult to determine if the population served data from DEERS is accurate.			
Relevance: The measure draws on multiple data sources which may not be simple to gather and may not be timely.			

Appendix C: Tobyhanna Leak Detection


Figure B1. Poster of Tobyhanna Leak Detection Program.




Acoustic Leak Detection

Facts:

- 54 acoustic leak detection sensors have been installed across the water distribution system.
- Sensors listen for water leaks each morning between 0200 and 0400.
- Radios transmit results between 0900 and 1500.
- A rover unit is used to collect leak sensor data.
- Sensors hold data for 60 days before the oldest data is overwritten.



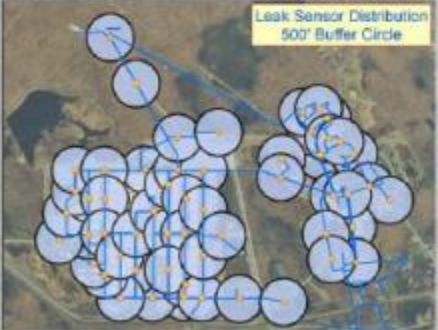
Listening for leaks before a sensor is placed in service



Data being downloaded from rover unit and displayed on map

Benefits:

- The acoustic leak sensors successfully identified eight water leaks through routine monthly surveillance from March 2011 to September 2011. The repaired leaks decreased water use by over 46,000 gallons per day and help lower annual water use to 58.8 million gallons in FY11 (FY10 water use was 75.8 million gallons).
- 16,999,321 gallons of potable water saved, \$29,459 cost savings, three year payback on the initial investment of \$88,000.



Sensor distribution map

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Figure B2. Tobyhanna leak detection-results of survey.



Figure B3. Tobyhanna leak detection-location of loggers.

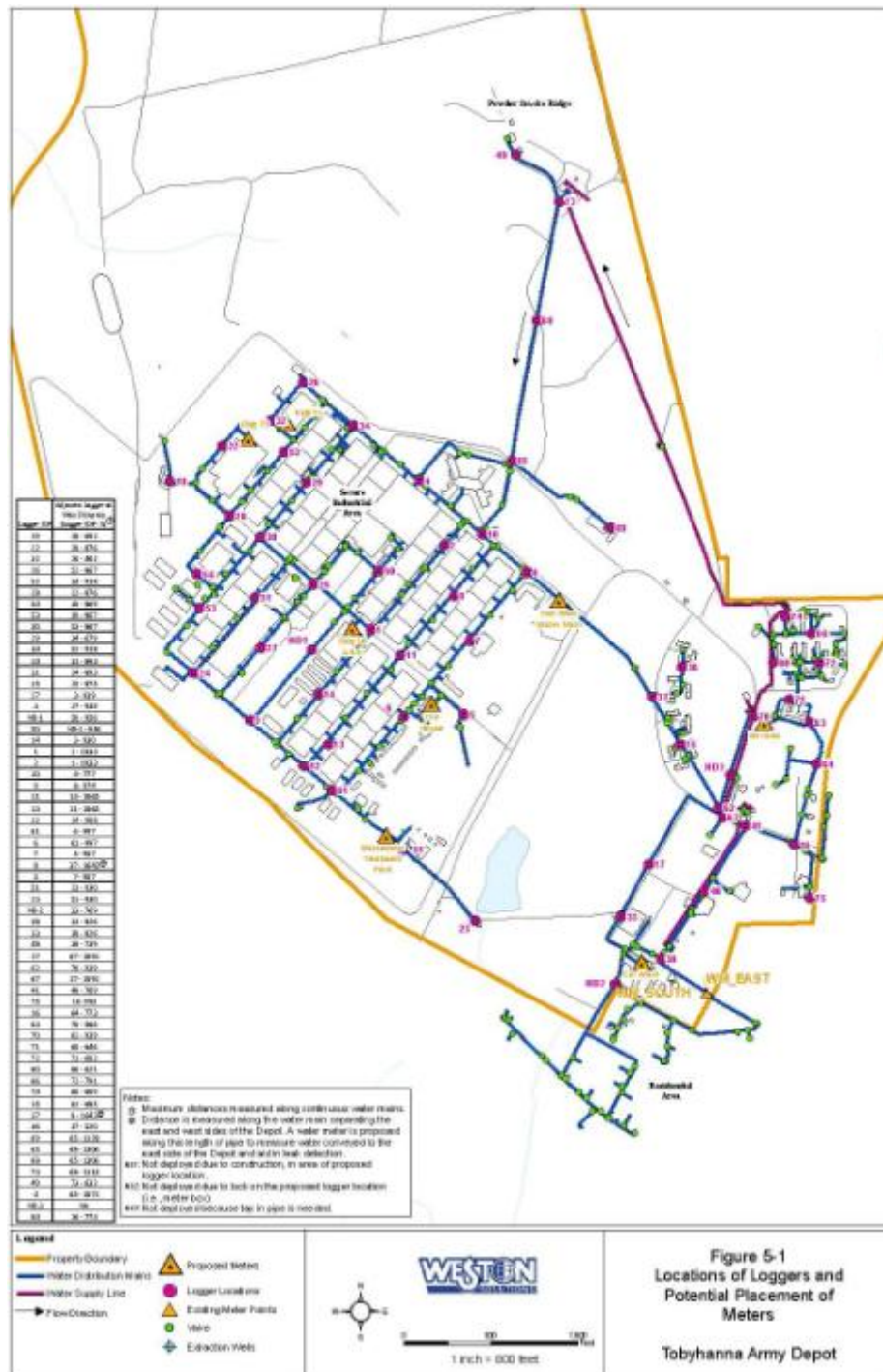


Figure B4. Tobyhanna Logger Locations in Secure Area.



Appendix D: Fort Carson Leak Detection Map

Figure C1. Fort Carson Leak Detection Survey map.



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